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Agro-food innovation system dynamics in India:
In search for a transition management approach for sustainability

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Introduction

This article examines the socio-technical connections of the inability of Indian nation state to complete the task of agrarian transition. It shows that the technology regime of green revolution is certainly not anymore in position to tackle in a sustainable way the contemporary challenge of food security and absorption of surplus labour in India. It describes the process of evolution of failures of the Indian pathway of green revolution (GR) as being determined not only by the limitations imposed upon by the inability to complete land reforms but also by the limits of selected technology regime of green revolution arriving earlier than expected that the agro-food innovation system is unable to deal with in an adequate way. It shows that the failures of agro-food innovation system are attributable to the simple fact that it was constructed, developed and maintained for the extension of mainly the narrow technological trajectory of disseminating high external input responsive varieties to the richer farmers that are operating in the well endowed regions.

It points out that the problems arising out of the technology regime of green revolution which the policymakers had built for the dissemination of an extremely narrow technological trajectory are now manifest in the form of agro-food production system having across the regions poor capacity for labour absorption, highly vulnerable to mono-cropping related environmental costs, highly neglectful of soil and water management, concentration on the adoption of rice-wheat crop rotation in regions where it has made the farmers only vulnerable to ecological stresses and shocks, irrational use of scarce external inputs, lack of emphasis on the generation of technological know-how for small

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holdings that are growing rapidly in numbers, etc., in the case of India. It suggests that the above mentioned limits of Indian green revolution technology regime and agro-food innovation system are now required to be treated as an important institutional barrier in the further advancement of agrarian transition in India.

It studies the latest status of socio-economic and environmental impacts being experienced in the country on account of the continued adoption of technology of semi-dwarf varieties of wheat and rice which was introduced with the objective to overcome food shortages and increase production of food grains in the second half of sixties in India. It analyses the role and impact of the co-evolved system of agro-food innovation that the policymakers built over the period of last forty years to innovate and diffuse the technology of green revolution in India. It brings out how the system of agro-food innovation has been shaped by the political bureaucratic leadership as a non-neutral "social carrier of agricultural science and technology" to serve priority the narrow interests of landed gentry that uses decadent semi-feudal relations of production.

It shows that the use of high external input responsive agricultural technology is being continued in the farm fields and in the laboratory by the STI institutions of the system of agro-food innovation without caring for the adverse socio-economic and environmental impacts. It traces the sources of inertia and rigidity of the STI institutions built in the course of the advancement of agrarian transition under construction from the above to the processes of STI put in place by the political bureaucratic leadership and continued by the scientific community leaders till this date in the name of increased food production. It shows that the origin of failures of the agro-food innovation system are to be traced to the way in which the STI processes were conceived and have been continued to be built by the leadership to achieve closest possible alignment with the goals of a narrowly conceived strategy of technology transition. It shows that the selection of technology transition strategy and associated STI processes happened in close collaboration with the policymakers of USAID and other related agencies in the interest of landed gentry in the post-independent period in India.

It suggests that serious concerns are now seemingly arising about the wisdom of persisting with the Indian green revolution (GR) technology regime because the nation

state is also redefining its role and handing over the management of agrarian transition to the agribusiness without bothering about the worsening of conditions of peasantry and rural labour and social, economic and environmental consequences that the country is being made to face as a whole. It shows that the socio-economic situation of peasantry and rural labour is becoming worse and the nature of technological adjustment being made by the agribusiness is making the system of agricultural production much more prone to shocks and stresses getting generated now in the system of agricultural production. It suggests that the agribusiness driven agro-food innovation system would not be able to resolve the agrarian question to the satisfaction of peasantry and rural labour.

It argues that the new web of theory, policy and practice is required to be shaped through the perusal of experiments in alternate schooling of the peasants, rural labour and consumers in order to overcome the rapidly deepening crisis of rural economy and achieve sustainability in the prevailing system of agricultural production in India. It suggests that the systems of innovation framework would be better placed if the theoretical approach of socio-technical systems is valorized and extended by the literature in the direction of analyzing the systems as non-neutral social carriers of science and technology. It reviews the experience of attempts being made for the niche formation in respect of an alternate social carrier of agricultural science and technology through the initiatives that have been undertaken by the highly committed individuals and grass root organizations for the implementation of integrated agro-ecological farming or organic agriculture approach in India to be on the whole positive. It concludes that it is not impossible for the movements of peasantry and rural labour to be stimulated and organised to practice socio-technical approach or social design of agricultural technology for effective contribution to a satisfactory resolution of the agrarian question in a less developed country like India.

This article is composed of three sections. Section 1 reviews the scholarship undertaken on the subject of management of agrarian transition in the less developed world by the development economists and shows that how almost all the schools of development economics have ended up till now only in sidelining the issue of determinants of agricultural technology and technical change while studying the agrarian question in

India. It assesses the theories, policies and practice of various kinds of schools of thought operating worldwide on the question of management of agrarian transition with the objective of assessing their contribution to shaping of the dynamics of "as existing" agro-food innovation system in India.

Section 2 evaluates the economic and technological performance of the "as existing" system of agro-food innovation with a view to delineate the nature of its role on the one hand in the achievement of extent of completion of agrarian transition and on the other in the kind of failures experienced in tackling the challenge of sustainable agriculture in India. The emerging corporate agriculture based socio-technical transition is also assessed briefly to evaluate the sustainability of this new socio-technical regime in making under the processes of liberalization, privatization and globalization in the Indian context. It studies the experience of analysis of policy making for agriculture undertaken by the political bureaucratic leadership and of the constitution of scientific community in the field of agriculture in the light of treatment meted out to technical change on the basis of the assessments undertaken by both these actors in India. It analyses the contribution of Indo-American S&T partnership (s) for the development of agro-food innovation system with a view to assess the implications of different paths to internationalization of innovation policy.

Section 3 suggests that as the proposed new context of agricultural development goes beyond the achievement of continuing only with the objective of increased food production through any kind of technology regime of green revolution (GR) the policymakers would have to adopt the emerging systematic framework of "socio-technical transition management" to understand the problems of sustainable development of economy in rural areas. The author concludes with the suggestion that the new heuristic proposed here in this article for the analysis of agro-food innovation system as a social carrier of agricultural S&T within the socio-technical framework of innovation management can help the policymakers to provide a peasant and rural labour friendly agro-innovation system and offer a set of longer term solutions for the achievement of sustainability in agriculture in India.

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Section 1

Agrarian transition management, development economics and socio-technical approaches

In less developed countries the issue of possible manner of resolution of agrarian question in contemporary conditions is very much an important concern for the practitioners of development economics. Scholars continue to produce a large amount of literature on agriculture in the field of development economics. A large part of this literature has been aimed at an appropriate explanation of the patterns of success and failure of agrarian transition in less developed countries. In the field of development economics, the issue of dynamics of agrarian transition is about determining the conditions and factors responsible for the completion / incompletion of all those changes in the countryside that are necessary to the overall development of capitalism or of socialism, and to the ultimate dominance of either of those modes of production in a particular national social formation in less developed countries. Below we bring out some of the important concerns that continue to attract the attention of scholars working in the field of development economics.

Scholars bring out how peasant production in contemporary conditions continues to exhibit even today the tendency of class differentiation. With no dearth of arrested, blocked or incomplete transitions in the great variety of historical contexts the students of development economics have been extremely prolific in respect of providing their own respective explanation of how the class of peasantry continues to persist in a differentiated form without being transformed into capitalist farmers and wage labourers in a large number of less developed countries. Much of this literature has been however pursued in the framework of political economy dealing with the problem of success and failure in technology diffusion and not of technological innovation. It remains largely concerned with making investigations into the socio-economic effects of technology or changes in question that make the transition possible or impossible.

Berstein and Byres (2001) suggest investigations in this field being mainly constituted around three central themes and the connections between them. The first cluster focuses especially, if not exclusively, on the social relations and forms of agricultural production (its class character and dynamics) and their effects for the means of poduction / productive forces deployed and the paths of technical change or (stagnation). The second cluster concerns the places of different forms of agriculture in social division of labour, factor and commodity markets, and commodity chains, within national economies and the international economy. The third cluster considers how those economic spaces are shaped by the relative strengths of different agrarian classes in wider political structures and processes, including those of state policy and practice.

Bernstein and Byres (2001) also point out in the same review that while there is occurring a great discussion on the social relations and forms of agricultural production, technical aspects of labour processes, and technical change tend to be restricted to the descriptive or contextual protocal, with few exceptions being (e.g. Byres 1981; Scott 1985; Pandian 1987). Pandian (1987, 61), in fact, commented on the inadequate interest in analysing the productive forces in the intense debate on peasant capitalism and agrarian transition in India. They point out that in this context, as in others, reference to the technical basis of agriculture, technical change, focused mainly on how it reflects and stimulates class diffentiation, how mechanisation is adopted to substitute for labour and / or to facilitate the restructuring of labour processes in other ways, as labour becomes more scarce and/ or more costly, better organised, more militant, and so on.

This means that contributions from the field of development economics remain focused on the development of social relations of capitalism in agriculture in less developed countries. The question of development of productive forces is rarely investigated; but as shown by Berensten and Byres (2001), Byres (2008) even when pursued investigations have been only dedicated to looking into the institutions connected with the diffusion of technology in agriculture and the precise form taken by the process of agrarian transition in the history of capitalism. Very few contributions are known to have engaged with theorising issues of technical change rather than assuming it, or sought to analyse its determinants (rather than effects) in particular social and ecological conditions of

production. Bernstein and Byres (2001) also admit that if the treatment of technology and technical change exhibited notable lacunae, the same applies a fortiori to consideration of the ecological conditions of farming and environmental change, with a few notable exceptions (Bray 1983; Pandian 1987).

In fact, even when Byres (2006) made recently a review of the currently popular variants of neo-classical theorizing on development of agriculture, namely the "new neo-classical development economics" (NNCDE) and the "neo-classical neo-populism" of Griffin, Khan and Ickowitz (GKI), he himself fails to refer to the issue of determinants of technical change and inform us of their understanding in this regard[2]. Although it can be seen that Byres (2006) criticizes the NNCDE to be inadequate rightly in the following respects: its assumption of the existence of a homogenous peasantry rather than the differentiated peasantries; its positioning of relationships of mutuality rather than exploitation in countryside; its assumption of parity of economic power rather than the asymmetry of economic power among social classes; its neglect of the causes of economic backwardness; and its defective view of the state, but in what way these aspects are dealt in the approach of NNCDE (not affected) is not even referred to. And even when the question of choice and effects of agricultural technology is discussed in the contxt of discussing the GKI approach Byres (2006) takes a deterministic view of technology. For example, the spread of new technology, and as part of that, adoption of mechanisation, is discussed by Byres (2006) to make the point that the former advantage of small farmers is now replaced by the advantage of large farmers who can now introduce a new direct relationship between and productivity and size of holding. Large farms now have higher land productivity and indeed, must be seen, in neo-classical terms, to maximize total labour productivity.

The brief review undertaken here above shows that almost all the schools of thought in development economics across the board have been analysing the opportunities for

[2] Both these approaches in his view have appeal beyond the usual constituency of neo-classical economics because they depart from the extreme position of the 'Washington Consensus' (WC) economists and seem to how neoclassical economics with a human face: the former, for example, opposing the virluent anti-state position of the neo-classical views that underpinned the WC; and the latter advocating a seemingly ultra-radical, egalitarian, pro-poor redistributive land reform.

intervention to the state and society alike in terms of a deterministic view of agricultural technology. But we show here that there is much to be gained by taking a non-deterministic view of technology which the socio-technical approaches to innovation studies consciously pursue. We view in this article the pattern of success and failure realized in respect of agriculture as not merely related to the kind of changes experienced in production relations but also connected with the nature of productive forces coevolved in the course of technical change and advancement on the pathway chosen to achieve capitalist agrarian transition in the country. It is shown that the contemporary conditions for capitalist transition are pushing the state and society to take a different approach to the process of innovation. It is argued that the rate at which India is industrializing and able to transfer surplus labour from rural to urban areas is not capable of growing any faster with the help of the existing technology regime and tackling anymore the challenge of agrarian transition. The challenge demands a view based on social design of innovation if the state and society in India want to complete successfully the agrarian transition. The new pathway to agrarian transition would have to be shaped consciously by the rural labour and poor peasantry by developing the productive forces. They will have to work the technological opportunities available for harnessing to them for rural industrialisation. It is shown that they will have to participate in the creation of a new set of social carriers of technology by intervening in the politics of social design of agro-food innovation system. For technological accumulation they will have to mobilise themselves to act as the partners of scientists and technologists to shape the pathways of agrarian transition and rural industrialisation quite consciously in a manner that allows them to be in the driver seat.

It is clear to us that the policymakers would not be able to resolve the question of agrarian transition to the satisfaction of peasantry and rural labour only by deploying short term relief measures, making incremental technological adjustments and looking into the compensatory mechanisms. Today they are required to go into the socio-technical connections of the existing agro-food innovation system. Today the social, economic and environmental concerns are quite intimately interlocked with the socio-technical nature of technology regime under development. The theory and practice of this

new challenge can gain substantially from the tradition of socio-technical approach under development now across in several countries in the light of the challenge of sustainable development.

Notwithstanding the above discussed virtual absence of any kind of substantive consideration to the determinants of technical change in agriculture, even the major schools of innovation studies do not perform any better with regard to the opening of the black box of technology. Quite a large part of this literature is concentrated on the issue of how the policymakers can do better by using the functional approach to the construction of innovation systems in order to facilitate the new and emerging technologies (agri-biotechnology, genetically engineered crops and animals) to gain a competitive edge in open economy situation. Below we analyse the contemporary challenge of reshaping of green revolution by making a journey in to its own past and show that the heuristics of new practice has much to gain from the perspective of development of a new social carrier of technology undertaking consciously social design of innovation rather than being misguided by the blind alleys of international business competitiveness oriented tradition of systems of innovation.

Section 2

2.1 Development economists and the discourse on Indian green revolution

Discoure on the start of green revolution phase in India has been shaped by the development economists of various shades including the version that belongs to the Marxist tradition of political economy. Scholars of development economics of all hues have told us time and again that the recurring food shortages were the main trigger for the political bureaucratic leadership to reconsider in the late 1950s the strategy of agricultural development selected by them immediately after gaining political independence in India. It was a step taken to tackle the crisis of food shortage, and the political bureaucratic leadership was in no position to consider an alternative because the consequences could have been serios and costs could have been high. From here onwards the story is about

the obvious that the policy makers had to adopt the 'new agricultural strategy' based on high yielding varieties of seeds and use of fertilizers and assured irrigation[3].

It is also true that even though the inherent limitations of this strategy were obvious very soon to development economists, only a few selected states became the food basket of the country while most of the agro-ecological regions lagged behind. Most of them were in favour of continuing the new strategy because the pathway was based on individual initiative of farmers in purchasing high input responsive higher yielding seeds and paying for assured irrigation, fertilizers and pesticides. For about two decades the key elements of "green revolution" were continued public investment in irrigation, roads and electricity, support in the form of input subsidies, cheap credit for the purchase of inputs, output procurement and price support, national breeding programmes, extension services and post-harvest operations related infrastructure development.

Development economists have very well documented that in the initial years the implementation of this new strategy led to an increase in food production and employment generation. They have also pointed out that this increase in productivity, however, was neither sustained over the years nor was it equitably spread over various states. States like Punjab, Haryana, a few pockets of Uttar Pradesh, Tamil Nadu, West Bengal and Andhra Pradesh generated food surplus for the entire country. Productivity increase in vegetables, fruits, sugarcane and other commercial crops have neither been sustained nor was it achieved by all the farmers. In recent years, the political bureaucratic leadership has been trying to see that farmers are encouraged to switch to commercial crops with expectation of multiplying their income. These crops involve higher investment in seeds, chemical fertilisers, pesticides and irrigation. A crop failure, decrease in commodity prices and inability to sell the crop leads to heavy losses to the farmers.

[3] Programmes such as the Intensive Agricultural Programmes (IADP) were initiated in selected districts. The IADP focussed on the use of high yielding variety (HYV) seeds, particularly those of wheat and paddy. This combined with the rest of the package of fertilisers and regulated and sufficient irrigation came to be known as the 'Green Revolution' (GR) technology or the HYV technology. In the 1970s, there was substantia l rise in productivity of various crops especially wheat.

The technology regime of green revolution was initially implemented in the irrigated regions through the efforts of well endowed rich farmers who had access to the inputs being provided by the state and could afford to take at least minimal risk in respect of the introduction of new technology. The limits on the expansion of area under cultivation necessitated the need for rapid increases in productivity of crops. This option of focussing on productivity of crops rather than redistribution of rural assets was preferred by the Indian state. The Indian state apparatus thought the new strategy of agricultural development to be easier one in implementation.

The green revolution was a phrase coined by the policymakers in the late sixties to refer to the adoption of the high yielding (or at least highly input responsive) varieties (HYVs) especially of wheat and rice. According to them the HYVs held out the prospect for spectacular increases in cereal production and the transformation of Indian agriculture. To buttress their argument the Indian policymakers had the enthusiastic support of the USAID, the Rockfeller and Ford Foundation. India developed its national system of innovation for agriculture and all the allied sectors including related industries to make the transition based on the "new socio-technical regime" of green revolution. The diffusion of HYVs and associated technologies (pump sets, small tractors, chemical fertilizers, pesticides, etc.) had the support of the Indian state, business world, landlords and rich peasants. Based on the assessment that land productivity increased faster than labour productivity as a result of the new technological packages of green revolution, along with the realization of the benefits of increasing employment and wages, faster increase in total factor productivity in agriculture than the fall in food prices, India went on to integrate the national system of innovation into the then emerging global system of innovation for agro-industrialization.

The "green revolution" strategy implemented in the 1970s however did not really lead to a spurt in overall growth but a concentrated rise in output levels in some areas. These were the areas which could meet the requirement of the "New Agricultural Technology' of assured irrigation and use of chemical fertilisers and pesticides. Today many more scholars concede that the growth strategy of the 1970s led to inter- regional and intra-regional differentiation on a large scale since it was biased in favour of areas with assured

irrigation and the capacity to invest in fertilisers and pesticides. Scholars like Bhalla and Tyagi concluded based on the data up to 1980-83 that in comparison to the 1970s, the spread of productivity increase expanded in the 1980s, but a large proportion of districts remained in 'the low productivity category throughout the two periods (1962-65 to 1970-73 and 1970-73 to 1980-83).'[4] Even they asserted that their study 'brings out that there are large disparities among districts with respect to their growth rates of output during both the periods.'[5] However, it is worth pointing out that scholars like Bhalla and Tyagi continued to maintain that the spread of HYV technology was uneven in the country due to 'unequal distribution of assured irrigation facilities and other infrastructure across regions.'[6] This means that even today they believe the green revolution technology to be scale and region neutral for the farmers. Some initial studies indicated also the unequalising impact of the growth strategy for agricultural sector.[7]

Many scholars have now noted that the unequal distribution of land assets in both fast growing and slow growing areas led to increasing inequalities in incomes. 'Due to these distortions, quite a large proportion of landless labourers and small and marginal farmers continue to live below the poverty line, more so in the slow growing regions of the country.'[8] By the mid eighties even the Agricultural Prices Commission (1984-85) was saying that 'nearly '70 percent of the incremental output of 18 million tonnes in 1983-84 over that of 1978-79 is expected to have emerged from the four states of Punjab, Haryana, Uttar Pradesh and Andhra Pradesh'[9] In the following year (1985-86) the Agricultural Prices Commission maintained that '… an analysis based on the indices of agricultural production for different states covering almost all the principal crops for the

[4] Bhalla and Tyagi page 202
[5] Bhalla and Tyagi page 202
[6] Bhalla and Tyagi page 1
[7] Mahendra Dev in his study on district wise analysis of agricultural performance also concluded that the relative share of high productivity districts in terms of area and output increased substantially during the mid 1970s and the relative share of low productivity of districts declined. (Quoted in Bhalla and Tyagi page 2)
[8] Bhalla and Tyagi page 1
[9] Bhalla and Tyagi page 2

period 1969-70 to 1983-84 also indicates that there exist large scale disparities in the regional pattern of agricultural development.'[10]

They have themselves begun to show that this kind of differentiation is only further accentuated since the 1990s with increasing privatisation and liberalisation. Various kinds of support measures that had initited and sustained the green revolution strategy until the late eighties were gradually slashed in terms of budgetary support in the period subsequent to the beginning of nineties. Many of these support measures are no more available to the system of Indian agriculture as a result of which there has been extreme fallout of agrarian crisis evidenced in the form of tragic suicides of farmers in many regions. Farmers have been swamped by indebtedness of enormous magnitudes in the areas which earlier benefited from the socio-technical regime of green revolution.

They have also shown that how the continuous decline in public investment in agriculture has further put pressure on the small and medium farmers to borrow to invest in facilities which were publicly available initially. The share of public investment in agriculture steadily declined during the past decade. Instead, the share of private investment has gone up which implies that small and marginal farmers have no access to the infrastructure created as a result of this investment. The crisis generated in the agricultural sector during the 1990s, which is also referred as the post-reform period, has its roots to a large extent in the lack of public investment in agriculture. The public sector investment has gone down in the past decade. There has also been a decline in gross capital formation. Various studies have shown 'that the share of the agriculture and allied products sector in the total capital formation has come down from 21 percent in the 1970s to 10.82% in the 1980s and further to 7.57 % in the 1990s.'[11] The share of agriculture 'in gross capital formation has declined from 15.4 % in 1980-81 to 8.6 % in 2001-02.'[12]; average annual capital formation in the public sector has gone down in absolute terms. 'As against an average gross capital formation of Rs. 6311 crores per annum in the public sector in the decade preceding the reforms, it is estimated that the amount declined to Rs. 4823 crores

[10] Bhalla and Tyagi page 2
[11] SP Singh Alternate Economic Survey 2004
[12] S P Singh ibid

in the post- reform period, and it was only Rs. 4676 crores in the past five years. The percentage share of the public sector investment in agriculture also declined from 11.16 from 1980-81 to 1990-91 to 6.34 between 1991-92 and 2001-02 and further to 5.74 during the past five years. Although the average annual private sector capital formation in agriculture has increased in absolute figures, from Rs. 8166 crores between 1980-81 and 1990-91 period to Rs. 14,625 crores during the last five years, its share in the total private sector capital formation has actually declined from 11.32 % in the 1980s to 8.50 % in the 1990s.'[13]

Development economists have been concerned about how the phenomenon of lack of investment in the agricultural capital formation has had negative effects on the sector. There has been a decline in the share of agriculture and allied sectors in the total gross capital formation. 'The share in total capital formation for agriculture and allied product sector has come down from 21 percent in 1970s to 10.82 percent in the 1980s and further to 7.57 percent in the 1990s… Its share in gross capital formation has declined sharply, from 15.4 percent in 1980-81 to 8.6 percent in 2001-02. …. The public sector investment in the same period has come down from 17.7 percent to 6.1 percent. The public sector capital formation has gone down in absolute terms as well as in percentage terms. The percentage share of the public sector investment in agriculture declined from 11.6 percent betweeen1980-81 and 1990-91 to 6.34 percent between 1991-91 and 2001-02 and further to 5.74 percent between 1997-98 and 2001-2002. Although the average private sector annual capital formation in agriculture has gone up in absolute terms, it has declined in percentage terms implying that in the post-reform period, other sectors have attracted much higher private sector investment as compared with agriculture.'[14] This has affected the spread of minor and medium irrigation projects as well as other public works, which enhance productivity and lead to general welfare.

It was understood from the beginning that the success of the HYV technology is dependent on the correct use of a number of agricultural inputs particularly irrigation. In this regard, development economists have been showing that the progress in providing

[13] S P Singh ibid
[14] S P Singh ibid

assured irrigation has not been very encouraging in the past two decades. The gross sown areas (GSA) increased from 176.75 million hectares in 1981-82 to 185.74 million hectares in 1990-91 to 192.62 million hectares in 1998-99. The gross irrigated area (GIA) increased from 51.41 million hectares in 1981-82 to 62.47 million hectares in 1990-91 to 75.55 million hectares in 1998-99. The Average Annual Growth Rate (AAGR) of GIA was 4.65% during 1981-82 and 1990-91 and it fell to 2.03% between 1992-93 and 1998-99.[15] It is the growth in minor irrigation that has been the main reason for increase in GIA; however, evidence indicates that this growth could be ascribed to private investment in this area. It is for this reason that minor irrigation has grown faster than medium and major irrigation. During the 1990s, area under minor irrigation increased by 21% as compared to 17% of medium and major irrigation. In recent years, evidence indicates a deceleration in the growth of minor irrigation due to decline in private investment.[16] This would imply that the amount of private investment especially by marginal, small and medium farmers in tube wells has begun to taper off. It is evident that public investment in irrigation plays an important role in making assured irrigation available to small and medium farmers in particular.[17] A marked decline in the consumption of pesticides has also been observed in the past decade. Furthermore, a deceleration in the implementation of soil conservation measures has taken place during the 1990s.[18]

The farmers have also experienced a rise in the cost of production with increased use of purchased seeds, fertilizers and pesticides accompanied with private investment in irrigation. The cost of cultivation as a result of the use of GR technology package has increased the most in Haryana and Punjab. The paid out costs or the actual expenses in cash and kind (A1) are nearly five times more for paddy in Haryana compared to that of Bihar. Use of fertiliser is also four to five times higher in the states of Punjab and Haryana. However, in terms of labour use measured in man- hours per hectare, Bihar uses nearly 917 units compared to 902 in Haryana and 585 in Punjab. As mentioned earlier, Punjab has the highest number of tractors per thousand hectares of GCA. As

[15] K.D.Saksena Economic Reforms The Indian Experience page 146
[16] K.D.Saksena Economic Reforms The Indian Experience page 146
[17] Saksena ibid page 150
[18] Saksena ibid page 150

opposed to that, Bihar uses the highest amount of draft animal measured in terms of pair-hours of bullocks. Cost for wheat cultivation is higher in Punjab as the use of bio-chemical and mechanical inputs is very high in this region.

This is certainly quite problematic for a country like India where close to 70 percent of the population is rural. Further, it is also apparent that the transfer of surplus labour from rural to urban areas or the management of surplus labour in rural areas through the ongoing agrarian transition in a productive way is becoming increasingly difficult for the less-developed emerging economies[19]. Evidence seems to be in fact gradually accumulating in almost all the regions in favour of the understanding that the crisis of agriculture is deep and wide enough to push the peasantry as a whole in these regions towards indebtedness, impoverishment, unemployment, food shortages and hunger[20].

The characteristic features of agrarian crisis are in fact evident in a highly acute form in quite a few parts in India. Manifestations of the crisis of green revolution are self-evident in the form of the resultant involuntary displacement of large masses of labour forced out of the rural, agricultural hinterland, and the near absence of alternative means of survival with dignity. Indebtedness, involuntary migration, hunger and suicides being present among the vulnerable sections of Indian peasantry in the states like Punjab, Andhra Pradesh and Maharashtra is indicative of the growing acuteness of the agrarian crisis in India[21]. Characteristics of the crisis are quantifiably visible in the way of severe reduction

19Even in a country like China where the growth rates have been higher compared to India throughout the period of last three decades 50 % of the population is still rural. The growth rate of Chinese farmers' net income per capita per year is also continually showing decline for the period of last one decade. There exists a serious problem of hidden unemployment or disguised employment within the vast numbers of the rural labour force. In fact, it has been estimated that the Indian nation would take close to 140 years at the prevailing rate to come to the stage of developed countries where not more than 8-10% of population is dependent on agriculture. This is however the case when we are thinking in a linear fashion; in fact it may even take a different turn and take much longer if the problems of ecological sustainability are allowed to worsen any further. Even after 60 years of industrial development India remains a country in which around 65% of the population is still dependent on agriculture for the livelihood.

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21 Widespread phenomenon of farmers' suicides and starvation deaths (Punjab, Andhra, Maharasthra, Orissa, and Kerala) constitutes a cruel testimony to this state of affairs. Deaths on account of suicides are reported from the areas that have been considered as prosperous and where the peasants have been involved in the cultivation of cash crops such as cotton and coffee. Starvation deaths have been largely reported from the areas that are poor and backward. These areas are drought prone and happen to be in the grip of moneylenders. These areas also lack alternate employment opportunities to ensure survival. For further

in labour days, reduction in wages and inability of existing agriculture to absorb additional labour[22]. The phenomenon of reverse tenancy is also on the rise. The impact on the dependent landless people is equally severe[23].

2.2 Failures of the pathway selected for green revolution and the nature of their connections with the agro-food innovation system

In this section, we continue to describe the growing adverse socio-economic and environmental consequences of selected pathway of green revolution. We show that how the political bureaucratic leadership and the scientific community leaders together have constructed on the one hand for increasing the food production and on the other hand for the completion of agrarian transition with the aim to create a class of capitalist farmers dependent on the agro-food innovation system which is directed at the moment completely from the above in India. We show how the failures of agro-food innovation system have been determined and linked to the way in which the STI institutions have been built by the political bureaucratic leadership and by the leaders of scientific community in close collaboration with the USAID.

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details see the writings of P.Sainath on starvation deaths and farmers' suicides in the Hindu and of Vandana Shiva and Kunwar Jalees on Farmers Suicides in India (2004).

[22] Take the number of those whose usual status is being that of employed in agriculture; decline in the annual rate of growth of the labour force is evident from the available statistics: 1.45 in 77-83, 0.33 in 83-88, 2.17 in 87-94, 0.18 in 93-00**.** The annual rate of growth of the labour force was 2.17 percent during 1987-88 to 1993-94 and only 0.18 per cent during 1993-94 to 1999-200. C.P. Chandersekhar and Jayati Ghosh have analysed the data on employment elasticities of output growth. They show that the employment elasticity of output with respect to the agricultural labour force changed quite drastically (0.70 in 83-93/94 to 0.01 in 93-00). Further, data provided by the Comprehensive Scheme of the Collection of Cost of Production of Major Crops in India and analysed by Abhijit Sen too suggests a decline in the rate of growth of overall labour use (Abhijit Sen, 2002). In Haryana, the intensity of employment has come down to the extremely low figure of 40 & 100 days of employment in a year for women and men respectively; Kerala, 51-110 & 69-145 days of employment for women and men respectively (cited in V.K. Ramachandran, 2005).

[23] The exodus to urban centres in search of employment has accentuated, resulting in ever-increasing outgrowth of slums around all urban centres. The struggles for occupying available land and for securing a living wage for landless labour have become more intense and violent. The situation is explosive and threatens to destabilize the social and political fabric. The lack of employment opportunities and income have resulted in an unprecedented reduction in the per capita availability of food-grains for the rural poor, pushing as large as three quarters of the rural population below " the poverty line". See Utsa Patnaik, "The Republic of Hunger" (2004) for the details.

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We describe the sources of inertia and rigidities being shown by the agro-food innovation system to reside in the mode and processes of alignment of goals of education, research and extension selected and constituted by the policymakers. We describe the growing costs of not being able to shift the country away from the existing pathway and technology regime of green revolution as being related to the assumption that there exists as yet no alternative to the selected regime of technology of green revolution and that the use of a high level of external inputs of chemical fertilizers, pesticides and water is at the moment necessary for increasing the food production in India.

We examine the historically determined socio-political process of fast sharpening contradictions of the pathway of green revolution selected by the political bureaucratic leadership in India. We have shown that though there existed alternate conceptions of the pathway to be taken for agricultural development which had been collectively articulated by the nationalist forces immediately after gaining freedom in their pronouncements and in the committees set up for national planning of agriculture and rural universities for agricultural modernization but the policymakers had abandoned these conceptions to embrace the selected pathway of green revolution to be constructed from the above without hurting the power of landed gentry in any major way.

We point out that the political economy was evolving in favour of the pathway of capitalist agrarian transition to be built from the above by the State, which was geared to use the technology regime of green revolution without even going through the measures of completion of land reforms, building of infrastructure for public system of irrigation and cooperative movement of marginal and small farmers. We bring out that the agro-food innovation system is today therefore quite insufficiently prepared to tackle the second order consequences of adoption of the narrow technological trajectory in the system of agricultural production in India. It is even less ready to be deployed by the country to achieve the goals of sustainability in India. The system of agro-food innovation must be radically transformed to serve the goals of sustainability outlined in the Indian context of agricultural development.

2.3 Social determinants of the success and failure of pre-green revolution agriculture

In order to make clear the significance of the point that the co-evolving political economy was a determining factor for the choice of the capitalist path of agrarian transition based on the technology regime of green revolution, it is necessary to recapitulate here firstly the history of pre-green revolution period in brief. Three most important initiatives taken after independence were firstly, land reforms, implemented half heartedly, were instrumental in making self-cultivation possible through peasantry to some extent in most parts of India. Although in certain states this did create the basis for the necessary institutional structure wherein the cultivators who had in their possession self-owned farms of some reasonable size or were in a fortunate position of being inheritors of secure tenancy could positively respond to economic incentives, but since the legislations on ceilings on landholdings and tenancy were implemented half heartedly the ownership of landholdings remained highly skewed and unequal and the conditions of tenancy quite unfavourable for many still in India. Today, in almost all the states, marginal and small farmers with ownership holdings less than 2 hectares constitute nearly 75-80% of the total holdings and account for only above 40% of the owned area. The distribution of operated holdings is equally skewed. The preponderance of small and marginal farmers is a key feature of the present agrarian scene. Often this feature prompts many scholars and policymakers to bring it to the fore as one of the most serious institutional barrier to large scale modernised farming in India.

The second initiative was to increase investment in irrigation and other rural infrastructure with a view to increasing the productivity of land; many hydroelectric and irrigation projects were initiated and completed during the first three plan periods.In terms of physical achievements like additional area brought under cultivation, additional gross area irrigated, and electricity generated etc., the record was not bad. The record till 1964-65, the entire Nehru period, in terms of growth of agricultural output was satisfactory. This point does need to be understood because during this period the growth of crop output was much higher than during any other decade except the 1980s and was significantly higher than the one achieved during the post-liberalisation period of the

1990s. A decomposition of growth of crop output shows that the area growth was the nain source of growth of output during this period although yield growth also made some contribution. The initiative of rapid expansion of irrigation through public investment was considerably weakened after the mid sixties. Policymakers were in favour of stimulating now the cultivators to embrace the practice of undertaking private investment in ground water exploitation.

The third initiative was the launching of the Community Development Programme and the Extension programme. These were conceived as programmes that would be instrumental not only in increasing the knowledge base of the farmers but also instilling in them the sense of self-reliance and cooperation for directly involving them in the process of development. Cooperative movement was thought as the solution to the problems of small holdings. Land consolidation through cooperative farming was expected to enable the small farmers to reap economies of scale without losing their entitlement to land. However, the problems of failure of land reforms, emergence of rich peasantry, continuation of landlordism in many parts, political bureaucratic leadership being apathetic to encouraging the small and marginal farmers to undertake cooperation in production, etc., all these problems were responsible for failure of the cooperative movement. Even where there was some headway, it is known that the cooperative societies were reduced to making the farmers to come together only for the purpose of credit, input supply and output marketing. In fact, at least in the case of small and marginal farmers later everywhere, the failure of cooperative movement was ultimately also an important institutional barrier for the spread of green revolution technology, which was considered by many to be a factor that would possibly facilitate only the making of a new post-green revolution technology regime in India.

2.4 Choice of the pathway of green revolution, co-evolving system of agricultural production and the nature of socio-technical outcomes

To overcome the situation of ‘agricultural stagnation’, a new strategy of agricultural development was formulated during the years of 66-67. The new policy marked a notable shift in the perception of what constituted the crucial constraint in the agrarian sector.

While writing on the characteristics and consequences of new agricultural policy, Sukhamoy Chakravarti, an eminent academic and member of Indian Planning Commission during the 1970s points out about this shift in the following way, earlier theorizing had maintained that it was basically the absence of knowledge of appropriate agricultural practice, along with the maintenance of an obsolete social structure, which prevented increases in agricultural production. The new strategy seemed to deny the critical importance of land reform even on the level of principle. Instead, emphasis was shifted towards technological modernisation (S. Chahravarty 1987, p24).

The US connection of this strategy was noted by S. Chakravarti in the following way: based on recently released papers of Lyndon Johnson, some commentators maintain that President Johnson lent a helping hand to the new strategy by withholding orders for the shipment of grains to India pending India's adopting a new package of policies comprising the following set of measures: 1) a shift in emphasis from 'major' to 'minor' irrigation works, which implied largely a shift from publicly financed large irrigation projects to small tube wells and energized pump sets; 2) adequate provision of 'credit' to those who were considered to be credit worthy, which in effect meant the large farmers; 3) an alteration in the input base of agriculture, which meant an increase in the rate of fertilizer consumption along with commercial sources of energy, such as electricity and diesel oil; and 4) the development of fertiliser-sensitive varieties of grains (S. Chakravarti 1987, p25).

Continuing with the task of recording vicissitudes in the career of a strategy, S. Chakravarti writes, "The new strategy seems to have had a very impressive effect in the case of wheat, but it is not possible to discern a similar effect on other crops, at least in the earlier years-and even with wheat, the impact was most pronounced in states already well endowed with such infrastructure as adequate roads, market towns, cooperative credit societies, and above all, good irrigation coverage." Moving further in the direction of consequences, he writes certain irreversible changes produced within the Indian economy, which pose problems for the future of Indian planning.

First of all, he mentions about the increase in the use of purchased inputs in the agricultural sector and the need to ensure flows from industry to agriculture could no longer be ignored. Second, that the monetization of Indian agriculture increased drastically as a far greater proportion of output began to be exchanged against money. Third, introduction of a price-support policy on a fairly remunerative basis, initially for wheat and later for other crops, introduced a downward rigidity in agricultural prices. Fourth, significantly greater use of energy and oil based fertilisers not only changed the cummulative capital-output ratio of agricultural production in India, but also made it far more sensitive to fluctuations in the world market-and particularly in oil prices.

As far as the above noted features are concerned, he has been quite prophetic in his reading of the consequences. But as far as the question of labour displacement is concerned, he was not as wholesome in his comments. He held that the green revolution did not lead to the type of labour displacement from agriculture which was predicted by some, mostly radical economists. He suggested that the increase in capital intensity in Indian agriculture, especially during the 1970s, has helped to achieve an increase in output per unit of land as well as per agricultural worker, in the face of severe land constraint and rising agricultural population. He dismissed the fears of labour expulsion from agriculture leading to greater urban unemployment. This observation is found to be less wholesome today when we find that quite a large part of employment is nothing but hidden unemployment, which is proving to be quite burdensome for rural economy today. However, he did criticize the scale neutrality assumption on the grounds that a) necessary capital had to be obtained on the basis of market transactions, b) the working capital requirement per unit of output was higher for the new technology and c) the gross-inequities in credit system made the well-to-do farmers the main beneficiaries. Although he did note that agricultural stagnation was broken (which is also not totally true), but it was accepted by him that it did so at the price of increased polarisation within the countryside.

In the later period, green revolution technology adoption led to what kind of consequences has been discussed in a number of contradictory ways. Some commentators

from the scientific community that a number of major changes have occurred: 1) slow and steady gains continue to be achieved in terms of yields per day, because of shortened plant growth cycles, 2) average yields achieved by farmers have risen significantly, including in many crops and regions that did not benefit substantially from the early green revolution, while also conceding that more recently farm-level yield increases in rice, wheat, and maize seem to have slowed down (although total factor productivity may have accelerated), 3) the area that is intensity cropped has expanded significantly, 4) emerging resource scarcities, environmental degradation, and resulting cost pressures have led to the development and adoption of many new resource and input conserving practices and 5) responding to rising wages, farmers have steadily substituted mechanical power for labour (Golin, Morris & Byrelee, 2005).

Many others have now started assessing the pros and cons differently. They have begun to take a different kind of stance on the impacts of the choice of pathway of green revolution. They argue that after more than a decade, in spite of the all-out support by governments and international institutions, the seeming success of green revolution had begun to fade. First, social concerns took the centre stage of the critique. Later, critics brought increasingly environmental aspects into the discussion. Since the late 1980s scientists of IRRI acknowledge the problems caused by indiscriminate pesticide use and the decreasing soil fertility (and yields) in fields constantly cropped with rice. The problems created are considerable. Today, it dawns on many experts that they can no longer fix the problems simply by further technological adjustments in the existing technology regime of green revolution.

2.5 Emerging socio-political challenge, technology regime & the pathway of transformation of green revolution

Further consideration of the political concerns also points out that the fact of increased differentiation of the peasantry and its political manifestation became considerably over the period more pronounced in the post-66-67 era. For example, attempt at mobilisation of surplus by the state through increase in taxation was resisted in the regions of green revolution. Today even when it is becoming clear that the economic and environmental

sustainability of green revolution technology is now a serious problem it is still a factor with the policymakers in keeping the technology regime of green revolution going. Since India's food security is dependent in the short run on this technology regime, many radical economists are taking a stand that no major step should be taken to destabilise the path of green revolution. Their demand is that the State support should continue for now. Let the experiments of alternate technology be conducted in all those regions where the technology regime of green revolution was not able to make a strong headway. Of course, we all know that after the post-liberalisation reforms the State has been however reluctant to carry the economic burden of support mechanisms. The impact of this change in the State strategy is very well beginning to show its adverse social, economic and environmental consequences for the green revolution regions too.

In the rest of India where agriculture is still backward, the character of contradictions remained different. The condition of the mass of peasantry and agricultural labour continues to be bad in these regions. However, it needs to be pointed out that for the policymakers the factor of influx of immigrant labour coming from the backward areas to the regions of green revolution came to act as a factor which relieved the tensions between the agricultural labour and the affluent farmers, explaining how in these parts the prediction of green revolution becoming red revolution of some radical economists came to be a red herring. In fact, the red element of Indian politics grew far more in those regions that were relatively speaking agriculturally backward for the policymakers. The agrarian scene is at the moment politically explosive. But as the country is still not being able to successfully undertake the task of articulation of a new development strategy to move further in respect of completing the capitalist agrarian transition the costs of this failure that is clearly systemic in nature are clearly massive for the rural and urban poor whose livelihoods and food security are really in jeopardy.

With about 16.8 percent of the world's population (1100 million, 2006) and 15 percent of the world's livestock population, India has only about 4 percent of the world's fresh water resources and occupies only 2.42 percent of its area to meet the ever increasing demand of food grains. The net sown area in the past 30 years has remained tatic between

138 million ha to 142 million ha. Between 1971-72 and 2002-03, the size of land holdings declined from 2.2 ha to 1.4 ha. The proportion of small holdings in the total number of holdings increased from 68 percent to 86 percent, which in actual terms has more than doubled from 38 million to 87 million during this period. Therefore, in the view of many scholars now the key issue is becoming one of how should a country like India where 65 -70 % of the population is dependent on agriculture for the livelihood security make the changes in the short run without destabilising the security aspect and construct the longer-term pathway for the sector of agriculture.

Below we summarize the socio-economic concerns of the present agrarian scene in the words of S.P. Shukla, Former Finance Secretary, Member Planning Commission and GATT Ambassdor in the WTO negotiations. In terms of the specific features of the crisis that the Indian rural economy faces today, he points out that: "In India, the present agrarian scene is characterised by:(a) large masses of marginal and small peasants with holdings not exceeding two hectares (constituting about 80 % of total operational holdings and accounting for 36 % of the total cultivated area as estimated officially in 1995-96) practising virtually subsistence agriculture and the prevalence of large masses of landless workers (the official estimate being 10.7 crores in 2001); (b) relatively much smaller numbers of middle and large landholders with holdings larger than four and ten hectares respectively, (constituting about 7 % of the total operational holdings and accounting for 40 % of the total cultivated area) practising capitalist agriculture; (c) intrusion of the agents of the corporate agriculture through the enhanced control of the system of input supply and agricultural markets; (d) incipient direct entry of the corporate sector into systems of farming through the increased control of finance, machinery, technology and retail food markets; (e) large scale migration of agricultural labour from areas characterised by (a) to areas characterised by (b) and (c); (f) total inadequacy of (b), (c) and (d) to cope with the additions to labour force in the rural areas; stunted growth of the secondary sector for the past decades, and the recent policy -induced tendency in that sector to adopt labour saving/displacing technologies, further reducing the scope for alternative employment; and the consequent prevalence of low/subsistence wages for agricultural/rural labour

everywhere (and also in the so-called "services" sector mushrooming in the urban areas); (g) increasing integration of the Indian agriculture with the world agriculture markets endangering the livelihood of peasants and landless labour [vide (a)] and adversely affecting even better off farmers [vide (b)] , but opening up prospects of definite gains for the Corporate sector[vide (c) and (d)]. The agrarian situation is marked by contradictions, old as well as new. There is persisting and deepening contradiction between (a) and (b). The relationship between (b), on the one hand, and (c) and (d), on the other, is marked by collaboration as well as conflict, the contradictory tendency sharpening with the ongoing integration with and the cyclical downturn in the world agriculture market. The State policy is clearly in favour of (c) and (d), somewhat ambivalent towards (b) and indifferent, if not antagonistic to (a). It is convergent with Agreement on Agriculture (AoA) paradigm. It is leading to sharpening of contradictions" (S.P. Shukla, 2005).

2.6 Towards an assessment of the limits of possibilities available within the pathway selected for perusal of GR technological trajectory since the early nineties

It is becoming now only gradually clear that the pathway of agricultural transformation which is at the moment based on the perusal of a narrow technological trajectory and embedded in the socio-technical regime of green revolution would itself have to be innovated to resolve the agrarian question in India. This can be seen from the cost of cultivation data generated by M.V. Raghvan in May-June 2008 (Raghvan M.V, 2008). Raghvan (2008), which is unequivocal in establishing that coinciding with the economic reform expenses on farming have soared to unprecedented heights. Raghvan (2008) points out that "while while fixed costs seemed to exhibit a gradual deceleration, operational costs have continued their relentless acceleration. The former reflects the prolonged depression in farm prices during the period under analysis and the resultant decline in private investments in agriculture. On the other hand, with the slashing of subsidies and the state agencies becoming redundant in distributing inputs, farmers naturally fell into the hands of unscrupuls private operators. This was instrumental in escalating operational costs."

Further, Raghvan (2008) also shows that "during the period, there has been a deceleration in the rate of growth of chemical fertilisers applied in cultivation. Nonetheless, the corresponding rate of growth of fertiliser charges was three times higher than that of its physical application." Continuing with the issue of the way the costs of inputs is rising, Raghvan (2008) shows that "the average expenses of six items (hired human labour, hired machine labour, chemical fertilisers, insecticides, irrigation charges and interest on short-term working capital) in the cost of cultivation of wheat in Madha Pradesh and Punjab is more than five times above the level in the 1980s. In Haryana and Uttar Pradesh, it was still higher." However, what is even more damaging in the observations of Raghvan (2008) for the survival of the technology regime of green revolution is that even if the input subsidy regime continued the costs of cultivation of wheat, one of the most state protected crops, could have increased faster than the increase in the general price level. This shows the weakness of that regime (input subsidy regime) because the paid-out costs of crucial items of agricultural inputs increase at a rate that had not been seen earlier". The second major observation is that during the post-reform period, there has been a steep decline in the labour hours applied in cultivation as also stagnation in casual wages. See Table 1 for the results of surveys indicating how a steep decline in labour hours applied in cultivation is finally showing up in the conditions of rural labour. Continuing with the economic dimension, Singh, Kaur and Kingra indicate on the basis of their latest survey of Punjab, the home of green revolution, that 89 percent of farm households in Punjab are indebted and all farm size categories are equally indebted in percentage terms (Sukhpal Singh et.al, 2008).

Further, there is now consensus emerging that food prices are not going to return to their earlier (pre-2006) level; Ramesh Chand (2008) puts it dramatically that "it seems difficult this time to prove Malthus and others, who made earlier such predictions, wrong." In the way of drawing conclusion on the global food situation, even Ramesh Chand (2008) of NCAP, ICAR now makes the case for a shift away from green revolution regime, and suggests that alternatives like organic farming could also reduce the impact of rising prices of fertiliser on food prices. The world may be forced to embrace genetically modified food crops, which can give higher output per unit input. Further, as the global

market becomes less dependable, food self-sufficiency would become really crucial for food security."

2.7 Changing expectations regarding the possibilities available within the selected technology trajectory

In the above analysis our focus was on the economic concerns arising out of the problems of continuing with the pathway of agrarian transition undertaken from the above based on the technology regime of green revolution. Environmental, health and socio-economic concerns were left unaccounted for in the analysis being done by the development economists. India is the highest consumer among the South Asian Countries (P.K. Shetty, 2001). Shetty states that the very agro-inputs, responsible for increasing agricultural production, are slowly showing signs of threats to environment, health and socio-economic well being of the community. Besides, monoculture and continuous cultivation of high input responsive varieties, over-lapping of cropping seasons, and excessive application of agro-chemicals, have resulted in high incidence of pests and diseases in many parts of the country. He also stresses that in spite of an increase in use of pesticides annually one third of potential food production is lost due to crop pests. Many innocuous pests of previous decades have attained the status of serious pests in recent years. Pesticides are poisons, and, hence they have detrimental effects on any organisms having physiological functions common with that of target organisms. Over-use of pesticides has brought about a decline in the biodiversity of non-target organisms in the hot spots. Shetty describes that farmers in the hot spots are overburdened with increasing costs of cultivation, a deleterious credit system, declining productivity, increased incidence of pests and diseases. A gradual transformation from chemical based farming practices to eco-friendly alternatives, such as diversification in cropping pattern, crop rotation, organic or green manure, integrated pest and disease management and integrated nutrient management are essential to achieve a long-term sustainable food production.

Environmental concerns arising out of the strategy of agricultural development that followed are not related to only the use of pesticides. The latest estimates reported by NBBS&LUP, Nagpur using Global Assessment of Soil Degradation Guidelines

(GLASOD) indicate 187.8 Mha of land degraded to various degrees and by various degrading processes. Ministry of agriculture estimates indicate the degraded land area to be in the range of 107.43 Mha by eliminating duplication of area reclaimed which is also included in the other estimates. Whatever is the extent of the area, the fact remains that soil degradation is the most serious problem and maximum degradation is by water erosion. The NBBS&LUP estimates of water erosion indicate 132.5 Mha losses of topsoil and 16.4 Mha of Soil terrain deformations.

Recently only V.N. Sharda, Director, Central Soil & Water Conservation Research and Training Institute (2007) stated his views in detail on the question of soil and water health in terms of the determinants. He makes the point that the steady growth of human and livestock population, widespread incidence of poverty, and the current phase of liberalisation, are exerting heavy pressure on India's limited land resources for competing uses in forestry, agriculture, pasture, human settlements and industries thus leading to severe land degradation problems. On the issue of magnitude of this problem, he clarifies that "as per latest estimates (NBBS&LUP, 2005), about 45 percent of total geographical area (TGA) (146m ha) in the country is affected by various degradation processes with water erosion being the chief contributor (28.6 percent of TGA).------ The negative environmental impacts of land degradation include loss of biodiversity and ecological stability, frequent occurrences of floods and droughts, silting up of reservoirs and changes in hydrological regime. Land degradation due to water erosion causes 5 percent to more thn 50 percent decline in total agricultural output every year, which is roughly equivalent to Rs. 55252-8400 crores. With the adoption of appropriate soil and water conservation measures the average productivity in these lands can be enhanced by 1.39 tons per hectare from 0.82 tons per hectare to 2.2 tons per hectare. Based on these estimates, if 5.5 m ha area affected by water erosion is treated each year with 50 percent success rate, the expected increase in production by 2025 may be about 77 metric tonnes which with 75 percent success rate may increase to about 115 metric tonnes. It is therefore not difficult to see that how "Self-sufficiency in foodgrains production", a key gain of the green revolution period, has come at a huge price of land degradation and

depleting water tables. Intensive irrigated farming led to environmental stresses like salinity and water logging of soils.

Sharda (2007) therefore states, "The targeted growth in agriculture would require further expansion of irrigated area through development of limited water resources which would be a costly affair in the context of competing demands with other sectors of water use[24]. The present level of foodgrain production (around 200mt) needs to be drastically increased to around 300 mt by 2020 and 415 mt by 2050." In such a situation the agricultural development strategy implications are clear that the technology regime of green revolution would be reaching its limits also in respect of the ultimate agro-ecological constraint of soil and water conservation. Sharda (2007) states, "Even after achieving the ultimate irrigation potential of 140 mt ha, nearly 40 percent of the total cultivable area in the country would still remain rainfed. The rainfed areas which constitute about 63 percent of the cultivated land account for only 45 percent of the total foodgrain production as compared to 37 percent of the irrigated area, which accounts for 55 percent of the total output to the national food basket. Most of the rainfed lands are also marginal and fragile lands subject to varying degree of degradation processes and are strongly linked to poverty stricken rural population. Hence, to avert food crisis in future, it is imperative to adopt two pronged strategies, viz; (1) checking degradation of agricultural lands to maintain proper soil health, and (2) conserve rainwater for its effective utilization and enhancement of crop productivity on sustainable basis."

Neglect of the measures of soil and water conservation has been a direct consequence of the pathway of agrarian transition from the above. It needs to be pointed out that the gigantic task is not limited to adding appropriate soil and water conservation measures for those rainfed areas which were so far left out from the scope of the strategy of agricultural development because the focus of agricultural growth during the green revolution era remained largely confined to irrigated areas and the rainfed areas were

[24] The per capita availability of water has reduced progressively to 1703 cum in 2005. With the projected future population, the per capita water availability may further decline to about 1340 cum by the year 2025. Considering per capita utilizable water for various uses, Sharda (2007) states that the situation would be more serious as it would decline from 1093 cum in 2001 to 808 cum in 2025. Thus there would be a shortfall of 27.4 percent in utilizable water to meet the water demand.

mostly neglected. However, there were also adverse consequences for the health of soil and water because of choosing the technology regime of green revolution to carry out the agrarian transition from the above by the state due to the way the regime was constituted and allowed to become a prisoner of the vested interests.

It is also quite obvious from the above discussion on the economic and environmental concerns that failure of the agro-food innovation system went to the extent that it was not even possible for both the scientific community as well as the political bureaucratic leadership to succeed even in the implementation of incremental technology adjustments to tackle the second order consequences of the choice made in respect of the selection of GR technology regime. Below we trace the story of how has this situation of inertia and rigidities come to stay for quite some time and show that why the change is becoming difficult without changing the beliefs, expectations and behaviour of actors involved including their relative influence on the conduct of various functions in respect of innovation management in the agro-food innovation system. We point out that as the institutional arrangements of Indian agro food innovation system got constituted in a highly myopic way through the Indo-American Partnership forged during the period of green revolution the system is not able to respond to the problems arising out of second order consequences.

2.8 Determinants of the failure of technology adjustment in the nature of agro-food innovation system

In this sub-section, we propose to discuss the evidence available on the failure of the agro-food innovation system to deliver with regard to the implementation of technologies for the maintenance of levels of productivity already achieved by the existing system of agricultural production. Failures of the system of agro-food innovation cover today a wide range of dimensions. Failures are viewed to exist not only in respect of failing to implement the technological adjustments of incremental nature but also not being able to build a system of discovery and development of agricultural science and technology for providing the solutions to problems of sustainability of agriculture in an appropriate and systemic way. The arrow of breakdown points towards the direction of the failure of

policymakers to undertake the required systemic changes in the system of education and innovation alike for the achievement of well identified productivity and sustainability gaps.

Evidence analysed below suggests that a number of important failures of the system of agro-food innovation are mostly attributable to the inability of the existing processes and structures of institutionalised agricultural knowledge production system to undertake the required technological adjustments to deal with the second-order consequences of high external input responsive varieties adoption by the farming population. Today it is quite clear to everybody that the past success of GR was embedded in the subsidised system of input supply created from the above by the government over which until recently the state sector used to provide a measure of some control to the political bureaucratic leadership. It is shown that though both, the scientific community and the political and bureaucratic leadership had a fair amount of leverage to make technology adjustments and make even the existing technology regime of green revolution less costly and more beneficial, but it is apparent that they failed to make those adjustments. Inappropriate handling of the aspect of technology implementation is itself today an important factor in the continuing stagnation in yield levels.

Even the latest publication entitled "Measures of impact of Science and Technology in India: Agriculture and Rural Development", which has been authored by one of the parent figure M.S. Swaminathan's own organization (M.S. Swaminathan Research Foundation, 2007, p xxiii) recognises the failure of technology implementation system and its consequences for the Indian agriculture. It states, "We cannot be silent on-lookers to the continued co-existence of mountains of affordable technology and acute agrarian distress". Whether or not there exists ready-made mountains of affordable technologies, but the fact of the matter is that these technologies continue to exist then only on the shelf as potentially transferable technologies. But the failure remains unexplained in this work which is otherwise quite well researched. It does not seek an answer to the question of how come the lab to land gap which has been a matter of 'active' consideration now for almost twenty five years remains unsolved till this day.

If the yield gap in the case of cereals is remaining high, it is due to the lack of capacity for transfer of appropriate technologies for agro-ecological management. In India, food supply is dominated by rice and wheat, which account for about 90% of the region's total cereal production[25]. Growth in the area planted to rice and wheat in India has slowed considerably, future production gains will have to come mainly from yield increases. Although average rice and wheat yields rose at about 2% per year between 1960 and 1990, evidence is accumulating to suggest that the impressive rates of yield growth achieved earlier are no longer being sustained. In some intensively cultivated areas, yields of rice and wheat have actually begun to decline. Slower growth in yields is alarming, especially since the use of productivity-enhancing inputs now seems to be approaching saturation levels. Fertilizer use on rice and wheat is now close to optimal, and addition of additional fertilizer is unprofitable. Although causes of the slow down in productivity growth are still in the process of being understood by researchers, their conclusions are clearly in the direction of pointing out that soil-related problems[26], problems relating to declining water tables, problems of salinity and sodicity[27], increase

[25] Over the longer term, most analysts believe production increases will be hard pressed to keep pace with even modest growth in demand, and they suggest that the challenge of development of improved production technologies is a formidable one. South Asia's rice-wheat cropping systems, which cover 12 million hectares, are concentrated on the Indo-Gangetic and Brahmaputra floodplains and the foothills of Himalayas. About 32% of total rice area and 42% of wheat area in the region comes under rice-wheat cropping systems, which can also include legumes, oilseeds, fodder crops, vegetables, sugarcane. Crop production is often linked to livestock production. (Peter Hobbs and Michael Morris, 200

[26] Puddling of rice soils leads to the breakdown of soil aggregates, resulting in reduced pore sizes and the formation in some soils of a plow pan. Puddling restricts water movement and affects soil reactions that are favourable for rice but unfavourable for wheat. Puddling may be one of the major causes, linked to it is the problem of poor rooting. Poor rooting of wheat following rice (because of poor soil structure, waterlogging and root-restricting soil layers) may be a major cause of declining productivity in wheat. Soil biological actors are relatively less researched. Cassman and Pingali (1995) hypothesise that the main cause of declining rice yields has been a reduction in the soil's natural ability to provide nitrogen, which they attribute to interactions between organic matter and soil microbes. Concern

[27] Concern over water availability has mounted especially fast in Northwestern India. During the past decade, water tables have dropped at a rate of 0.5-0.8 m per year in the state of Haryana and at a rate of 0.2-1.0 m per year in the neighbouring state of Punjab. Declining water tables not only raise production costs, but such rapid rates of decline raise serious questions about the long-term sustainability of rice-wheat systems. In some areas, farmers are already being forced to cut back on the number of irrigations, and where water shortages are acute, they are sometimes forced to limit plantings. Poor water management practices are leading to the aggravation of the problems related to soil salinity and sodicity, which in turn are affecting soil productivity.

in the incidence of pests and diseases, build-up of grassy weeds[28], delayed planting of wheat following rice that reduces yield[29], are the key reasons.

In India in different parts the rapid spread of canal irrigation has resulted in the development of the problems of large-scale water logging (2.45 mha) and soil salinity/alkalinity (3.30mha). Intensive cultivation of the high input responsive varieties of crops removes substantial quantities of major nutrients such as nitrogen, phosphorous, potassium, iron and sulphur, and minor nutrients such as Zinc, manganese, boron and copper. Nitrogen and phosphorous are removed in large quantities when grain yields of the order of 7 to 8 t/ha are harvested in a year, as in many double-cropped irrigated areas[30]. There is evidence that farmers have been removing more nutrients from the soil than they have been adding by way of fertilizers.

ICAR (1998) study indicates the aggravation of imbalances for Haryana during the period of 1966-96. In Haryana; there is also evidence that the organic carbon content has declined from 0.5% to 0.2%. Consequently, nitrogen-use efficiency by the crops has been adversely affected and more inorganic Nitrogenous fertilizers are required to harvest the same yields as 20 years ago. It is said such imbalances are continuing to evolve today at a higher rate than before because of the rising costs of chemical fertilizers. All of these factors point to the lack of sustainability of growth in crop yields in the long run.

From the above discussion it is now amply clear that the current practices of technology management must change even if we want to reduce the yield gap between the laboratory

[28] Phalaris Minor, a grassy weed which poses problems or wheat, is a major problem of the rice-wheat cropping systems. If left unchecked, this can cause crop losses in wheat of nearly 100%. Reports are that this weed is developing resistance to isoproturon, the most extensively used herbicide in India. The rice-wheat system has expanded the host environment for many insects. The result is the appearance of overlapping generations of insects. Leaf diseases in rice and karnal bunt and foliar blights in wheat are arising. Lack of varietal diversification is a serious problem.

[29] Management decisions taken to increase the productivity of one crop have negative consequences for the productivity of other crop in the rotation. Reduced tillage considered to be a solution for fertilizer uptake efficiency and yield increase in wheat creates new problems; stem borer carryover in unplowed rice stubble.

[30] For example, a rice-wheat cropping system yielding 6.95 tons/ha of rice and 3.86 t/ha of wheat removes 316 kg of nitrogen and significant amounts of phosphorous, potassium and other secondary micronutrients (yadav 2000)

and farms. It would involve the development of technologies of agro-ecological management for diverse agro-ecological resource endowment situations. It is not that knowledge for the development of such technologies cannot be created. The fact of the matter is that presently the system is not able to provide space to the development of technologies for agro-ecological management. It is our case that the as existing system of technology implementation is just not geared to handling the issues arising out of diversity existing in respect of the agro-ecological regions and farmers' resource endowments [31]. Later we provide more evidence of how come this kind of failure in the system is persisting and the managers are unable to correct it at least for a period of more than one decade.

Take the aspect of technology generation for the sector of agriculture. Even in respect of the technology component in which the agricultural universities were considered to be strongest research outcomes have been extremely disappointing during the decade of nineties. In the case of crop husbandry sector, the Varietal improvement programme, focusing on development of superior crop varieties through plant breeding, has been a vital component of the technology system chosen for introduction in the Indian agriculture during the green revolution phase. In this very technology component the decade of nineties was a period of complete stagnation in respect of research outcomes and knowledge utilisation; the Indian agricultural universities could not develop any new superior technological solutions needed to overcome the situation of persisting stagnation in agricultural productivity.

In the case of Wheat, the gain in yield declined significantly, from 3.17% in 1980s to 1.67% in 1990s. In the case of Wheat, the declining rate of increase in yield in the 1990s

[31] In a recently published review of the soil sciences research undertaken in India during 1975-2001, Rajeshwari Raina (2006) writes, "Location specificity demands interdisciplinary team work with a range of local partners. Both are unfortunately features that are discouraged by the patrons of soil science research, -----. Three sub-disciplines, soil science, soil chemistry and physics and soil fertility account for almost 82% of the Indian journal publications in soil sciences. This may be interpreted as a dominant feature of Indian soil science – three of the most popular sub disciplines that contribute yield-enhancing technologies in convergence with the green revolution paradigm and the commodity orientation in agricultural science in general.

has been attributed to lack of development of varieties with genetic gain in yield. In the case of wheat no new superior variety has come in the recent 10 years. In the case of Wheat Varietal Improvement programme, in 1963-65 Kalyansona, gave yields up to 5.3 /ha in experimental plots in northwest India. The latest best yielding variety, PBW-343 yields 5.6 t/ha. Other factors contributing towards this have been water scarcity and lack of moisture efficient genotypes, as well as increase in soil temperature (Nagarajan, 2006).

The situation is not in anyway better for the other crops. In rice for the last twenty-five years, no genotype has been developed with yield potential greater than IR 8 and Jaya (Nagarajan, 1998). The annual increase in yield declined in the case of rice from 32 kg per hectare in the period 1970-71 to 1990-91 to 20.6 kg per hectare in the 1990s. During the period 1965-2000 the number of varieties of rice released from different states/institutions of India was 620. Among the released modern varieties (MVs), 54% were recommended for the favourable irrigated ecosystem, 27% for the rainfed lowlands, and 19% for the rainfed upland favourable irrigated eco-system. Though even during the second phase of green revolution breeding for shorter duration MVs has received a considerable attention, most of the MVs were developed to meet the increasing demand for better quality rices. Similarly, though development of MVs with multiple resistant to insect pests and diseases has remained a priority in the breeding strategy since the eighties, but only 4% of total MV releases are resistant to more than one insect pest. The share of MVs with multiple resistant to diseases has declined from 10% during 1965-75 to 4% in the late 1990s.

Experiencing of the yield plateau is already a real problem for the introduction of MVs and for the system of agriculture that the Indian agricultural universities have been promoting till this day. The potential boundaries of this technology system have been arrived at. Beyond these boundaries yield levels cannot be increased in the case of MVs. However, it is also clear that the challenge posed before the system of knowledge production is far greater than before. Kumar (1998) has estimated the required production and productivity targets for individual commodities. His estimates show that the

productivity of rice needs to improve from 1.85 tons/ha to 2.9tons/ha in 2020, wheat from 2.42 to 3.92 tons/ha, and total food grains from 1.5 tons/ha to 2.4 tons per ha.

Particularly when the issue of sustainability of agricultural development has also come to the fore now in a big way; the question to be asked is whether the strategy of having a focus in the existing system of agricultural universities on the Varietal Improvement programme has been itself an appropriate strategy. For even the irrigated regions and well-endowed farmers the system has proved to be myopic. If the strategy of introduction of high yielding varieties which are also external input intensive including water as well as energy is not working for the irrigated regions, it is even less likely to work for the regions and farmers which are less favourable from the standpoint of the management of soil and water resources.

Further, it is also quite clear from the above discussion that the management limits of technological system of intensive agriculture are already serious enough to cause a major decline in the viability of intensive agriculture in the leading states of Haryana and Punjab and other green revolution areas of the country. The Indian Agricultural Universities have so far managed agriculture without taking into account the farming system perspective (limited to addressing the biophysical dimension of sustainability), regional natural resource management perspective (supposed to accommodate the social dimension of sustainability), regional-ecosystem-health perspective (expected to address the ecological, health, aesthetic and ethical dimension of sustainability). The fact of the matter is that the as existing system of agricultural universities is in no position to handle the issues of diversity pertaining to agro-ecological regions and farmers' resource endowments.

It is our understanding that the policymakers created a top-down system of technology implementation. It would have to be radically restructured if we wish to ensure an adequate agricultural growth rate in the country as a whole. The system policymakers recommended worked well only with regard to the proposed immediate objective of increasing food production for a small set of farmers in selected regions. But for it to be radically transformed to tackle the problems of diversity, we will have to also ask why

the system has not able to change gear even when the system of agricultural universities has been under severe criticism for the same reason for quite some time now[32].

2.9 Policymakers' vision of agro-food innovation system and the resultant structural rigidities

We can tackle the above described problem if it is recognised that the system developed structural rigidities in respect of even the implementation of incremental technological adjustments because the policymakers were instrumental in endorsing a system in which alternate technological and market niches had very little space or scope to get protection and time to stabilize. Some of the niches in respect of development of new markets are now being attended to by the system in collaboration with the corporate sector which the new Indo-US initiative is proposing to realise through the Agricultural Knowledge Initiative. During the first two decades the space for alternate technological approaches was very little because the proposed programme was also bearing the mission of dissemination of a borrowed technology package at a very high pace. There was hardly any space for the cultivation of basic sciences in the system. However, in our view, the space for work on technological alternatives was less not only due to the absence of emphasis on basic sciences but also on account of the way the role(s) of education, research and extension were integrated too tightly through a highly centralized system functioning under the influence of an extremely narrow mandate of how to increase the area under high yielding varieties.

In fact, finally the integration of the system of knowledge production and reproduction was for even a narrower mandate of the Varietal Improvement Programmes for cereals like Wheat and Rice. Even in the development of new varieties the incorporation of local

[32] Its vision and strategy was inadequately conceived for the dry land regions; it was clear and officially recognized by the National Commission on Agriculture (National Commission on Agriculture, 1976). See Dinesh Abrol, "American Involvement in Indian Agricultural Research", Social Scientist, New Delhi, August 1984, p 8-27 for further details. But even in the long run as the system has failed to provide remedies to the problems afflicting the Indian agriculture across agro-ecological regions, it would not be wrong to state that the vision and strategy of Kothari Commission should itself be questioned and given a fresh look. To reinforce the same point we also cite here late Suresh. K. Sinha, Former Director IARI, who wrote, "to ensure food security the country will have to give up the 1970s model of agricultural development" (Sinha, 2002).

germplasm in the plant breeding work was a highly neglected area. Too much accent was placed at least during the initial period on yield with little emphasis on quality, consumer acceptance, adaptability to local conditions, resistance to pests and diseases etc. Yield potential (or high yield) was the breeding objective for 89 percent of the crosses affected in rice breeding programmes in India, while only 9 percent of the crosses were for drought tolerance and only 2 percent for deep water tolerance. According to a study conducted by Janaiah and Hossain (2004) the percentage of varieties adopted by the farmers in their fields over the fourteen major rice growing States accounted for only 35% of total varieties released till 2000.

The unfortunate part of the story is that the warnings from concerned scientists were ignored and the situation was allowed to drift for a long time in the system[33]. This happened on account of the new system where the functions of research, teaching, extension and even adult education of farmers and related persons are combined into a single institution. The research facilities under the control of state government departments were to be transferred to the agricultural universities. But this networking and integration into a strictly regimented and centrally coordinated national technology transfer system built for the modernization of Indian agriculture with the help of a very specific technology system turned out to be its strength in the short run but its weakness even in the medium run. It is not that the Indian scientists were incapable of doing original work but it was the system that prevented them from pursuing the work of this nature. The peer groups and top authorities were well in the grip of the new package strategy and they saw to it that much effort was not "frittered away" on problems which were not pertinent to the new package strategy.

Many examples can be given to illustrate the point of how these rigidities have come about and what accounts for their resilience in the case of the SAUs and ICAR. Take the case of All India Coordinated Research Projects (AICRPs). For the transfer of HYV technology to succeed, both adaptive and protective research was required to some extent to change the original characteristics of HYVs to suit local conditions. For this, the

[33] See Dinesh Abrol (1984), p.15 for further details of the treatment that the system meted out to Dr. Richaria, Director of Central Rice Research Institute (CRRI).

national research capacity had to be spread over the various regional centres located in different ecological regions. Adaptive research work started in India with varieties imported from CIMMYT etc. Dinesh Abrol (1984) suggests, "Given the fact that the starting point was the foreign varieties and the charter was to modify the original characteristics only to a minimum, the effort did not have to go beyond the fostering of institutional structures required for adaptive research, field experimentation and tests for suggesting the requirements of complementary inputs.

Thus, as far as research is concerned, networking into all-India coordinated projects directed and controlled by a few institutions was its strength only in the short run because it permitted strict implementation of established crop improvement procedures for non-local internationally transmitted germplasm without much diversions and produced demonstration effects in quite a short time, judged by the general standards of efficiency of national technology transfer systems in other areas in the country[34]. But it was as well a weakness because it was geared to doing mainly adaptive research, testing and demonstration for HYVs, and had neglected fundamental research leaving the initiative to international agricultural research centres which provided the germplasm for plant-breeding work and strategies for the new farming system.

Changes have occurred and are continuing to occur even today in the system of research, education and extension, but it is evident that deeper structures prevent the system from making the required correctives. Incremental innovations characterize the system of research and education, and there too the forces directing the content of agricultural sciences is even today the forces that do not have the local conditions of the farmers in any way uppermost in their mind. Structures that the system initially fostered to get the best results for green revolution technology package have got rigidified; though their relevance for the current concerns is being increasingly questioned at all the levels now. Even the National Commission on Agriculture (1976) pointed out, "the undue concentration of coordinated projects in the ICAR institutes like the IARI and the IVRI is another undesirable feature and could have been avoided -------- Only for a very limited number of coordinated research projects are the headquarters located at the agricultural

[34] See Dinesh Abrol, American Involvement in Agricultural Research, Social scientist, 1984.

universities. ----- The same is true of adhoc research schemes. The IARI alone accounted for more than half of the total number of adhoc schemes in crop sciences for all the ICAR institutes in 1974-75. While all the agricultural universities put together accounted for 162 schemes, the IARI alone had 125 schemes in the area of crop sciences in the year 1974-75". This kind of centralization had made an adverse impact on the quality of education and extension and was observed in the Report of the National Commission on Agriculture (1976).

Furthermore, it is also important to recognize that the rigidities of deeper structures were inbuilt into the strategy of the collaborative programme itself. Priorities were clearly articulated to favour a system of adaptive research and training for the diffusion of a technology system that had already completed its development phase. But as the technology system needed adaptations to enable even the farmers who were not resource poor to adopt the high yielding varieties in the well endowed regions, the agricultural universities were required to carry out their tasks for the diffusion of these higher yielding, high input-responsive varieties in an integrated way. It wrote, "They should begin with and for some time concentrate on the traditional agricultural specialities such as agronomy, plant genetics, animal breeding, animal husbandry, veterinary science, plant pathology, soil science, microbiology, horticulture, entomology and parasitology.

Research was concentrated mainly on individual crops and their productivity. Research on farming systems which would take into consideration all the inputs, was either scant or totally absent. Recycling of agricultural wastes – as practised in many parts of the country – was absent as an objective in the agronomic experiments whose incorporation could provide nutrients. Soil microbiology, biological nitrogen fixation, microbial decomposition in soil, use of algae, etc, received relatively little emphasis in the research system because of obsession with high yielding varieties sensitive to chemical fertilizers. Neglect of water management emerged as the single most important consequence of the new strategy[35]. The fourth evaluation report of the IADP programme identified the lack

[35] See Dinesh Abrol (1984), p16.

of adequate research information and the non-availability of trained staff as the main difficulties in organising work in the area of water management[36].

Distortions were quite serious in the case of fundamental research in the established system of institutes and agricultural universities. The National Commission on Agriculture had to say the following with regard to the fundamental research being conducted in Indian agricultural universities: "What often passes as fundamental research in agriculture but a variation of similar study done elsewhere having little or no relevance to our conditions. ------Owing to continued lack of encouragement, this category of research has not gained growth in agricultural universities. The basic science faculties are too weak to sustain the desired leadership"[37].

The role conceived for the National System of Agricultural Research, Education and Extension was on the one hand, to strengthen adaptive research, protective research and testing and on the other hand, to provide the manpower needed for the package dissemination in the country. In the international division of labour in the research network, fundamental research was assigned to international agricultural research centres financed by the United States. Moseman, member of the first joint Indo-American team and director of Rockefeller Foundation's Agricultural Sciences Program wrote, "although these international centres cannot meet the specific national or local needs for research they will modify the nature of programs and organisations required in individual countries and *will permit an orderly phasing and evolution of national systems (italics added). Stronger initial emphasis can be placed on adaptive, protective and applied research within each country with emphasis on basic fundamental studies postponed until later."*[38]

The fact that the research, education and extension got geared to pushing mainly the HYVs package is not because there was any conspiracy hatched but because it was structurally evolved by conceiving a well defined division of labour between the

[36] See Dinesh Abrol (1984), p17.
[37] See also National Commission on Agriculture, Report on Research, Education Extension, 1976.
[38] Albert Moseman, Building Agricultural Research Systems in the Developing Nations, Agricultural Development Council Inc (ADC), New York, 1970, p. 101.

international, national and regional structures. Control through peer groups, which determined the system of reward and recognition, was a key mechanism for influencing the system. Whenever there was a need to rationalise the structures in order to solve the emerging conflicts, centralization and bureaucratic structures came handy. Reinforcing factors included exchange programmes for foreign travel. The National Commission on Agriculture (1976) wrote, "The craze (for foreign travel) has been so great that quite a few had to be warned recently and some suspended and dismissed".

But all of this was happening to a large extent because of the lack of indigenous assessment of priorities. Influential peer groups trained in the US, financed in many cases quite heavily in respect of their research programmes, directed the choices of curricula, research problems and extension strategies in different agro-ecological regions. All this combined with the ambitions of the young scientists to be able to work with those who have not only influence and authority because of their links with funding agencies but also status in the international community. The existing system of agricultural higher education lacks in all those characteristics that would allow integrating the system of education, research and extension for the cultivation of objectives pertaining to diversity, critical inquiry and self-reflection. The responsibility of not being able to provide the correctives to the farmers with regard to the technique lies squarely with the system of agricultural universities as it was made responsible for not only education but also for research and extension. The recommended system of integration was insufficiently modern. It should have had enough space for the creation of technological alternatives and self-reflection.

2.10 Agro-food innovation system and its American connection

We also need to recognize that the vision of the system that the policymakers approved was a socially designed non-neutral programme being evolved in the process of Indo-American Collaboration on agriculture. The Education Commission of 1964-66 was responsible for providing legitimacy to the programme being already worked out till the last dot amidst the administrators of agriculture through the Indo-American collaboration.

It was a first full-fledged nod from the side of educationists and education planners as a whole to the system of agricultural higher education already under construction.

The first Joint Indo-American team was formed in 1955 and had examined the entire field of agricultural higher education and research in India and to recommend improvements. An Indian delegation spent three months in the United States examining 'land grant universities' while an American team of three examined the situation of agricultural higher education in India. The joint team had urged that agricultural universities similar to those in the United States be established and that these institutions not offer postgraduate education unless their faculty conducted research. The team also recommended close ties between colleges of agriculture and technology (i.e. engineering) in each of the universities.

The central point in the Education Commission's recommendation, the establishment of at least one agricultural university on the suggested lines in each state, was in fact a recommendation of the Second Joint Indo-American team (ICAR 1960). Since the Indian government had formed this joint team with the U.S. with a view to evaluate progress made since the first team report in 1955[39] and to review the relations with the U.S. land-grant universities, which had already made the recommendations regarding the system of agricultural higher education to be established, the Kothari Commission was merely reinforcing it. It is indirectly admitted in the Kothari Commission when it states that how the programme is not new. All the additional suggestions that the Kothari Commission made on for education for agriculture in schools, polytechnics, universities and IITs are discussed later. They are shown to have been ignored by the system planners to a large extent.

Not only that the Education Commission (1964-66) was adopting a virtually ready-made programme, it appears that while formulating its vision and strategy regarding the system

[39] Lawrence Busch 1988 writes, "The Second Joint Indo-American team urged that the process of university development be expedited and that one agricultural university similar to a U.S. land-grant university be established in each state. All agricultural research was to be coordinated by ICAR. The Community Development Program's broad focus was to be narrowed and the program was to be ceded to the Ministry of Agriculture, a point that was subject of the some dispute among the Indian members of the joint team (ICAR 1960, 72-74)

for education for agriculture the Commission legitimized the ready-made programme without an appropriate scrutiny. There was an already set direction created by the government in respect of the planning of agricultural education during the decade of 1950s. And the reason for this lapse is obvious if one goes through the process of formulation and implementation of the Kothari Commission's own vision and strategy. It could not think afresh because the processes it followed were also not free from the direct influence of US interests. The influence of US interests would become sufficiently clear if we mention about their direct involvement in the vision and strategy formulation and later in the programme implementation. For example, Dr. Ralph W Cummings, the Director of Rockefeller Foundation in India was not only a member of the Kothari Commission but had a direct involvement in the programme implementation. It is true that the Kothari Commission had some very eminent educationists and scientists as also the members in the Task Force on Agriculture formed by it and that Dr. Ralph. W. Cummings was not alone in deciding on the issue of the vision and strategy. But what is often forgotten that he was also the in-charge of programme implementation. It is a matter of history that Dr. R.W Cummings also served later as a chairperson of the committee that planned the structures and criterion of performance for the Indian agricultural universities.

The report of the Agricultural Universities Committee (Cummings Committee) was the basis on which ICAR developed the Model Act, which was designed to guide state legislation concerning the creation of agricultural universities. First made available to the states in 1966, the Model Act enumerated the following four goals for the SAUs (ICAR 1981, 6): i) To impart education in different branches of study, particularly agriculture, horticulture, veterinary and animal sciences, and other allied branches of learning and scholarship; ii) To advance learning and research, particularly in agriculture and other allied sciences; iii) To extend knowledge gleaned from such sciences, especially to the rural people of the state; and 4) To achieve such other purposes as the university may determine from time to time.

The Cummings Committee visited the states of Punjab, Orissa, Rajasthan, Andhra Pradesh, Madhya Pradesh, Karnataka and Tamil Nadu. The committee visited a state only

upon a request from the state, forwarded through the Government of India, Ministry of Agriculture. Its principal charge was to review the proposals for agricultural universities in the various states with regard to the adequacy of the proposed enabling legislation and the adequacy and soundness of the detailed implementation plans in terms of organizational, administrative and educational criteria. But there comes the catch now and also a key lesson of policymaking. *Central support was to be made available for only those agricultural universities that met the criteria developed by the Agricultural Universities Committee.* USAID-US university assistance in agricultural education was restricted to those states that established agricultural universities in line with the recommendations made by the Agricultural Universities Committee (Cummings Committee).

During the 20-year period (1952-72), six US universities were involved in programmes that had their objectives the improvement of teaching, the establishment of research and extension activities in the new universities and in the existing agricultural colleges. During these twenty years, more than 300 staff members from the six US universities came to India, on either short or long term assignments and more than 1000 faculty members and graduate students studied in the U.S. This number does not include significant number of Indians who were supported through various fellowship programs or through their own funds and who received U.S. university degrees at both cooperating and other land-grant institutions. Nor does it include the many Indians trained at home at public and private agricultural colleges whose primary mission was and remains teaching. During these twenty years, almost 31 million US dollars and another 11 million US owned rupees were spent, and about 700 man-years of US staff were devoted to help India build the present system of agricultural research and education, including the creation of nine new agricultural universities.

Lawrence Busch (1988) states, “The 20-year period of intensive assistance to the SAUs can be described as the single largest agricultural education project ever undertaken by A.I.D--- Unlike the land-grant system in the United States, which developed over 125 years into a system that came to embrace research and extension as well as teaching, India’s SAU system sprang up virtually overnight as a full-fledged, comprehensive

system". Except for a few hitches here and there, from both the sides the participants of this program implemented it in a single-minded fashion. In those states where no agricultural university developed, all activities under the Agricultural Education and Research projects were phased out with the end of current commitments. The result was that each and every university tried not to deviate from the proposed model and criteria provided by the Central Government. Lawrence Busch (1988) writes, "This was in part a response to pressure from A.I.D-Washington to show that clearly demonstrable impacts were being felt."

However, an important lesson that we must take once again into account today is that the concept of institution building that was developed in the United States in the 1960s was a form of "social engineering" not limited to the system of education but also extended to the society and economy as a whole. Lawrence Busch (1988) also writes, "What went unnoticed, even by Hannah in his Blueprint (1956) was that the U.S. land-grant universities were embedded in a complex institutional matrix that included organized farm groups that lobbied at the state and federal levels for funding for agricultural research and education; a diverse far-flung system of agricultural credit; effective suppliers of agricultural inputs and processors of agricultural outputs; a farm constituency that was virtually entirely market oriented; an efficient system of transport of agricultural commodities; and well organized markets."

Very little resistance experienced by the system at the time of its establishment. As far as the forces that opposed the establishment of the model of new institutions is concerned, there were only those forces of opposition who had vested interests in the old order and had very little to contribute to the development of alternatives and corrections. It seems that the forces of resistance to the proposed specific technology system with which the fate of agricultural universities was linked were rather weak; organized powerful voices in both regional and class terms that could be said to also favour a different form of agriculture were missing from the agricultural scene at the time of establishment of agricultural universities. The aspect that got highlighted in the early seventies was related to the fact of technology being resource intensive and therefore the need to undertake land reforms and augment irrigation and credit facilities to allow them to benefit from the

new technology. In the eighties, when the experience of farmers with the technology had sufficiently grown, these forces also demanded that the scientists must not be content with the results obtaining from the experimental stations they must undertake on-farm research, change the extension system and solve the problems of smaller farms in a targeted way.

In the nineties, the situation was one of uncertainty and of even leading the country and system to accepting a position that the state need not step in to solve the problems of Indian agriculture. Let the private sector come into the system including research where the SAUs and the rest of the system should become a partner. Certainly from the last few years there is a change in the way the country now feels about the "green revolution" technology and has become concerned about the state of agricultural education, research and extension in a very different and radical way. Some of these forces are again demanding from the agricultural universities that they also devote energy to the problems of small farmers and become more pluralistic in approach to the production of knowledge[40].

It would not be out of place to mention here that the model of agricultural higher education that the Education Commission approved in 1964-66 was also quite different from the one that the Radhakrishnan University Education Commission (UEC) had envisaged to evolve for implementation in the country in 1948-49. It is to be noted that the Radhakrishnan Commission was not in favour of borrowing a readymade model because it believed that India should develop a model of her own kind after a thorough study. It was interested not only in taking the best features of the models of agricultural universities available in the world but also in selecting and adapting them for the development of a system of agriculture connected appropriately with the local resources, capabilities and markets. It was of the view that the system of education for the transformation of agriculture and village industries should be undertaken in an interconnected way by the rural university.

[40] See the report of M.S. Swaminathan chaired National Commission on Farmers, Ministry of Agriculture, GOI, New Delhi, 2006.

Even in the midst of all these distortions the SAUs and the rest of the national research and extension system have been able to generate several scientists, teachers and student outturns that have very different ideas about the priorities of Indian agriculture. There is a lot of churning going on at the level of both official and non-official programmes in the country. The resistance is coming from within the system; though yet a minority in terms of overall numbers within the system but it is putting a contest. The language has changed and it is showing in the recommendations of the committees set up officially by the ICAR and the other official arms of the Government of India. But there is a contest from the influences arising on account of the changing international agriculture regime. Today the corporate sector is far more important in research and production of agricultural inputs such as seeds. It is doing its best to force the public sector research and education system to get into a partnership with the business entities active not only in agricultural biotechnology but also all other areas of conventional technologies. The Indo-US Knowledge Initiative for Agriculture has succeeded in putting Monsanto and Wall-Mart in command once again within the public sector agricultural research, education and extension system. This contest of the forces is visible from the recommendations of the committees as well as the scientific and teachers community.

Furthermore, it is also apparent that the longer-term gigantic task can be only achieved by adopting a policy which seeks to promote technically sound, economically viable, environmentally non-degrading and socially acceptable use of the country's natural resources of land, water, climate, flora and fauna to promote sustainable development of agriculture. The challenge of doubly green revolution or evergreen revolution obviously seeks from the Indian State and Society to give the highest priority to the fulfillment of this gigantic task. The number of those scholars who hold a definite view on the issue of whether the time has come for a change in the technology regime of green revolution is growing. The grounds for socio-technical change are being recognised; however it is also clear that appropriate action on this front would follow only with the change in lens of both, theory and practice. For which the beginning has been made but the momentum would follow only when the social forces are able to absorb a new theoretical framework for the analysis of technology and systemic development of productive forces.

It is clear from the above described evidence that the system of STI for agro-food innovation functioned productively for selected regions in the short run. It was tightly tied to the narrow agenda of introduction and diffusion of the green revolution technology to the well endowed regions and relatively richer farmers who were capable of adopting the system with some profit. The imprint left on the organization of education, research and extension, which the state planned with the support of large sections of S&T community and richer farmers for the benefit of green revolution, is however shown to have therefore made the same agricultural universities to fail in respect of finding viable solutions for appropriate agricultural technology packages needed when the second order effects of technologies introduced earlier in the seventies and eighties are now most visibly manifest for even the segment of richer farmers. It is shown that the malfunctions had begun to develop very early and have got only rigidified further during the period of last thirty years. We have also shown that in spite of the available advance warnings the policymakers have failed to bring about appropriate systemic changes in the system of innovation including education for agriculture in time.

2.11 Transition to "Post-green revolution" trajectory compounds the crisis for producers as well as consumers

The current policymakers are now hoping to solve the agrarian crisis through an alternate route to the development of a different variety of capitalism in agriculture by facilitating the global integration of Indian agriculture and by pushing the system of contract farming and corporate input supply. But these measures are compounding the failures of Indian STI system further. Major worries have also arisen now with regard to food security, chronic hunger and malnutrition, adverse environmental changes in the form of increasing land degradation, water pollution and the loss of biodiversity, food safety and the continuing poverty of a vast majority of rural population. The management limits of technological system of intensive agriculture are already serious enough to cause a major decline in the viability of intensive agriculture in all green revolution states especially the leading states of Haryana and Punjab.

The system of STI has so far managed agriculture without taking into account the farming system perspective (limited to addressing the biophysical dimension of sustainability), regional natural resource management perspective (supposed to accommodate the social dimension of sustainability), regional-ecosystem-health perspective (expected to address the ecological, health, aesthetic and ethical dimension of sustainability). However, the latest Indo-American Agreement on Agricultural education and research with Wallmart and Monsanto on the governing board is further compounding the problems of Indian STI system and planning to move the system towards the priorities of "corporate agricultural biotechnology" and food processing. With a paltry 9 percent of the total investment in agricultural research it is threatening to take the system in the direction of control of priorities of the system in the hands of agribusiness. It is taking the system away from the priorities of location-specific soil and water management, crop rotation and biological agriculture that thanks to the efforts of some of the members of scientific community the leadership had chosen to work towards only recently in the Tenth Five year Plan[41]. However, since 2004 once again under the Indo-US Agricultural Knowledge Initiative, winds are seemingly blowing again in another direction altogether. The "as existing system of STI" of green revolution is being allowd to be redesigned for a new international division of labour in the area of global STI. It is another matter that the corporate sector is mostly failing on the front of introduction of agri-biotechnology and is in no position to handle the issues of diversity pertaining to agro-ecological regions and farmers' resource endowments.

This is happening because the nation has failed to recognise how the policymakers had even earlier created a purely top-down system of technology implementation under the earlier Joint-Indo-American Agricultural Research Cooperation Agreements which had very little space for agricultural sciences. But it is apparent that this time the impact is going to be adversely felt on the cultivation of not only science but also on technological autonomy as India is already a signatory to TRIPS Agreement and is obliged to implement a new system of IPRs for agri-biotechnology. As the aim is to promote a partnership which would end up subordinating the national system of knowledge supply

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to the strategies of corporate world, the values of agribusiness are already beginning to dominate in respect of technology generation through the Indo-US Agricultural Knowledge Initiative.

Even in this new agri-biotechnology based socio-technical transition the corporate sector is increasingly going to be itself in driver seat and is in search of those technologies that can be widely applied. Therefore, in this new srategy too there is apparently very little space for the cultivation of an integrated approach for the realization of values of ecological and social justice. In fact, this is becoming the case not only for the development of agri-biotechnologies and genetically engineered food crops but also for the development of organic agriculture. For the agro-food innovation system to be radically transformed to tackle the problems of diversity, we will have to get out of the current socio-technical regime of green revolution and work more vigorously to facilitate the socio-technical transition to a new type of socio-technical regime and a new kind of system of STI.

Section 3

3.1 Framing and negotiation of technology development for a new socio-technical regime

We have already stated that the socio-technical approach to pathway creation providing heuristics for the management of technology transitions is shown to perform better because it explicitly takes into account the question of sources of inertia and rigidities of the innovation system. But its treatment of the transition management is still not of much help to the policymakers if the rural labour and peasantry are also to take an active part in the social design of agri-food innovation. The prevailing socio-technical approaches do not bring out the importance of the necessity of application of a new heuristics of design of “who-whom” of technology regime for the creation of a new pathway of ever-green or doubly green revolution. We cannot assume the system of innovation and technology regime to be automatically non-neutral in their orientation.

It is clear from the above discussion that the proposed new context of agricultural development goes beyond the achievement of continuing only with the objective of increased food production through any kind of technology regime of green revolution. The policymakers are required to adopt a social design of innovation oriented framework of "socio-technical transition management" to understand the problems of sustainable development of economy in rural areas. Since as a non-neutral social carrier of agricultural S&T the Indian agro-food innovation system is presently geared to serving largely the interests of landed gentry and of at the most of rich peasants the question tackled in this section is how do we foster the institutional arrangements of a new social carrier of technology which is amenable to the influence of poor peasantry and agricultural labour.

The proposed heuristics should be designed to affect changes in the power structure, learning processes and priorities in respect of S&T and development goals to make an impact on the management of S&T expectations, beliefs and behaviour of the participating actors and the social design of who-whom of innovation. We discuss what kind of changes in the organisational structure and policies of the associations of peasantry and rural labour would be necessary to change the agro-food innovation system in respect of its learning and innovation orientation. We regard the issue of management of change in the orientation of agro-food innovation system to be a question of making the rural peasantry and labor capable of accessing and influencing the STI institutional arrangements and changing their socio-technical character.

Earlier we have clearly shown that the institutional arrangements of existing agro-food innovation system are embedded in the system of State Agricultural Universities (SAUs). These institutions will have to start resolving location-specific complex problems of natural resources management. It is also clear that for this transition policies and institutions concerning the incentives and performance evaluation, organization and management, and control and regulation of teaching, research and extension are required to be guided by a very different kind of ideology and values. Policies for the development of agriculture and rural economy will have to be conducive to the cultivation of a system of education for agriculture, which will value and allow and encourage the agricultural

universities to create a new ideology of research, expertise and service. It is important that the strategy of agricultural transformation plays itself a complementary role and provides synergy to the changes to be brought about in the system of education for agriculture and rural development.

Although as early as the year 1970 the National Commission on Agriculture was of the view that more attention be devoted to fundamental research, that only one SAU be established in each state, and that better linkages be established between research and agricultural extension for the dry land regions and the benefit of farmers who are not well endowed, but the system of agricultural universities could not respond to these priorities positively due to the policies and institutions being not favourable to the proposals. There was a mismatch between the priorities of those who were directing and managing the SAUs and all those who had begun to look at these institutions with a critical eye even within the administration of agriculture. Synergy was missing from the framework of coordination set up for the purpose of finding solutions to the problems of either small farmers or dry land regions.

For example, in 1977-78, when ICAR undertook an internal review of the SAUs (ICAR, 1978), the report that resulted from the review recommended only a rationalization within the model under implementation in the framework of further centralization around the package strategy. It recommended that all research facilities be transferred from the state governments to the SAUs; that the functions of teaching, research, and extension be better integrated; that each state has only one agricultural university; that high standards should be maintained in the appointment of vice-chancellors; and that new programs be established only when the requisite faculty and facilities were in place. Even when the same ICAR report urged that practical training programs be instituted for all undergraduates that more emphasis be given to training for self-employment, that home science be made more rural in its orientation, and that committees make faculty selection with larger numbers of outside experts, there was very little action on these proposals.

Even while recognizing that technical education is practiced differently as compared to general education in higher education institutions, but it needed to be certainly farsighted

and pluralistic in its approach to knowledge for problem solving. It is true that the system of technical education is all over the world oriented to problem solving. However, it is generally more tolerant, less targeted in its vision of technology system and target groups. Even in India if you look at the rest of the technical education system the system of agricultural higher education that the Education Commission endorsed was far less flexible and far more centralized. What the Education Commission endorsed in respect of agricultural education was not pluralistic and knowledge production wise autonomous; it was completely oblivious of diversity in agriculture. It was not at all appropriately modern in its approach to knowledge of agriculture. Although it created modern facilities for doing agricultural science in India, but the system constrained and restricted the system from doing science and generating appropriate technology.

Implicit in the story of agricultural universities, as it appears to have unfolded during the last four decades, is the naked truth of not only the system of agricultural education being closely tied to the U.S. universities and also largely limited to the adoption of a system of specific technology and institutions but also the fact of the system being built in such a way that in these organizations changes could only occur from the top down, not from bottom up, and persons with a measure of official authority or sanction must guide them. It is also clear that the other critical factor was the balance of forces engaged in promoting and resisting the strategy of implementation of the proposed programme of agricultural education, research and extension during these four decades. In the initial period, as shown, the strategy of programme implementation was deeply embedded in the web of well cultivated linkages of integration with the forces promoting the change to a system of agriculture dependent on HYVs and inputs produced outside the system of local economy. Further, we have also shown that the Government of India was already in the process of not only the implementation of the programme of establishment of agricultural universities but also in the creation of a system of input and output markets for the extension of the same specific technology in particular with the assistance being provided by the U.S. Agency for International Development (USAID) and the international agribusiness supplying the technology for the production of relevant inputs.

All these forces were an integral part to the social engineering of building of new institutions for agricultural higher education.

Thus, we are of view that the change must come about through a new framework of coordination of both, technology as well as rural production. Although the state would have to continue as a short-term strategy for some more time with the support for the purpose of relief to the farmers reeling under the current crisis and immediate food security but it is not possible for the Indian state, be of any kind, to keep the system of agriculture as a prisoner of the specific technology and production system which is becoming too costly for it to sustain. In the long run, the nation must switch to a sustainable system of agriculture. What that system would be is becoming clear now; it will have to be a system of chemical pesticide free or independent green agriculture in some regions and organic agriculture in other regions.

Unlike the Education Commission that ended up endorsing a centralized system of education, research and extension, the new system of education for agriculture would need to be flexible and pluralistic. It would have to be integrated and embedded in a system of sustainable development of rural areas. Its approach to produce location specific technologies would be systemic in character. It would have to rely far more on natural and social sciences that care for ecological and social justice than is the case today. However, it is also quite clear that the forces favouring a pluralistic, flexible and more rooted in rural economy are even now in contest with the forces favouring further integration with the emerging international agricultural regime. By signing the Indo-US Knowledge Initiative for Agriculture the government has made it clear that the forces favouring further integration with the agribusiness are still very powerful. It is also a fact that more strength will have to be gathered by the forces favouring sustainable development of agriculture and rural industries and services as a part of the process of developing the local economy as a system in itself without breaking its connections with the national and international S&T system. Even from some of the latest recommendations of the Planning Commission it is clear that the system planners are going through a process of internal struggle and many are interested to transform the

system of state agricultural universities (SAUs) in the country as per the national requirements.

In such a situation of contest; our proposals are aimed at the perusal of an institutional reform which would give space to the forces interested to follow the agricultural strategy, which promotes the agricultural production on the basis of the vision of making use of local resources and enhancing productivity without compromising sustainability. Technology systems for non-pesticide management compatible to green agriculture, low external input system of agriculture, biological agriculture, organic agriculture and other such systems would have to be integrated through the cultivation and promotion of an alternate set of forces through the development of an alternate policy for rural industrialization in which the development of local economies as a system is itself valued. Even the National Commission on Farmers reflects today the emerging contest to a large extent; the question is how we are going to strengthen the relevant forces in favour of an alternate strategy of sustainable development of rural economy and agriculture in the midst of changes taking place in the national and global economy.

In the Radhakrishnan Commission (UEC) 1948-49, the educationists had thought about a system of rural universities where a similar vision guided them in respect of agriculture and rural industrialization. This vision valued local artisan, peasant and agricultural labourer in a manner that comes quite close to the directions that the system of education as a whole has to take. The system favoured a strategy of using the advances of science to create such technology systems, which were to upgrade the village industries and agriculture as a system in itself. It means that the system would have allowed the nation to cultivate and promote an alternate set of forces in which the rural universities and professions to be created were to combine their energy with the farmers, artisans and agricultural labourers. It favoured not only establishment of the courses for agriculture in secondary schools but also integration of these schools with the rural universities for both research work and supply of motivated students for graduate and post graduate education.

But the forces working in favour of the model of rural universities were not very strong is also clear from the experience of rural institutes set up by the Gandhian forces in the

country through the Ministry of Human Resource Development. The 150th Report of the Parliamentary Standing Committee on Human Resource Development (August 2004) is of the opinion that the National Council of Rural Institutes has not become functional from 1995, the very day it was established. It is clear that what we have today in the form of rural institutes is by no means the alternative to the existing system. It can play a complementary role as it can be seen from the recommendations of a seminar, "Rural Higher Education towards Sustainable Village Development and Gram Swaraj" (June 2002) that these institutes had organized to develop their conception of the role these institutions would like to perform. There exists a system of agricultural schools and polytechnics that through the nation has not been very supportive of and needs to be integrated by the system planners into a new framework of coordination of technology and production for the development of local economies as a system in itself.

Linking of SAUs with several research and educational organizations will yield rich dividends in terms of faculty exchange and utilization of facilities. The linkage between traditional universities and SAUs could be fostered in area of fundamental research. Even within the agriculture sector, mobility within and between NARs/SAUs/DUs and networking ICAR/SAUs should be encouraged. The exchange of students and faculty with foreign institutes and outsourcing of faculty and networking among SAUs and national institutes could be tried out. Given the fact that the Government has limitations in carrying out extension activities, the small scale units manned by agricultural graduates/post-graduates who will have back up from and access to the agricultural universities and KVKs need to be given a bigger role in agriculture extension policies/ activities being planned / implemented by the State and Central Governments. Linking SAUs with Agro-industries to optimize resource utilization and for proper harnessing of technologies generated in the SAUs is another measure. The Fourth Deans Committee 2006 made it mandatory for each SAU to have linkage with at least one ICAR institute for formal research guidance and vice versa. It suggested that development grant should be linked with adoption of this reform.

As discussed in this section and implicitly in the critique part in the earlier sections, a lot is required to be done to improve the management of system of education for agriculture

in respect of academic, administrative and financial autonomy in India. It is undeniable that the Indian system of agricultural universities has not been able to provide for the culture of autonomy coupled with accountability. It is a recognised fact that the system could not grant space to those communities of practitioners who were required to be supported by the institutions for the exploration of technological alternatives and scientific knowledge needed for the management of diverse agro-ecological regions. Even from the way the Fourth Deans Committee has exhorted for the accreditation process to focus on the determination of infrastructure and manpower and maintained silence on all the other aspects, it is clear that the concerns discussed by us in Part I are yet to enter into the process of accreditation and evaluation. Similarly, when the leadership recommends that the quality of individual institutions be critically assessed, and the accreditation system should be made more stringent to enforce accountability (NAAS, 2005), the issue of what kind of meaning does the scientific community assigns today to the concept of quality and relevance in the context of current challenges remains an open question. In our view, this issue still needs an appropriate resolution. Diversity, self-reflection, critical inquiry, commitment to the "who-whom" of research and extension would have to be valued in the processes of generation of autonomy and enforcement of accountability.

3.2 Peoples' movements in India face a special challenge of sustainability and justice

To rework the vision of the existing system as a whole in line with the framework outlined, the systems planners should be asked to take the bold step of involving the forces that are active within the peasantry, agricultural labourers, artisans to organize them for a restructured innovation system to create the matrix of forces interested in the social engineering favouring sustainable development of rural economy and agriculture. There is no alternative to strengthening of the forces and organizing them for the establishment of networks for a new system of education for agriculture tied to the vision of transformation of national agriculture on the above-suggested lines. Needless to state that the forces favouring the agribusiness approach are stronger and far more organized and would have to be resisted through the establishment of a system of pluralistic and

flexible institutions to allow the forces of resistance to gather far more strength at the earliest in respect of knowledge production for an alternate system of agriculture and rural economy.

The peoples' movements would have to put in a huge effort to succeed in the development of new social carriers of techniques to achieve a desirable socio-technical transition in the case of agriculture and its allied sectors. For a sustainable development of rural areas India needs to chart out an altogether new alternte pathway to sustainability. Below we show that the peoples' movements are yet not organised very much to strengthen the efforts being made in this direction through experiments to persuade the Indian policy makers to pursue the governance of socio-technical transition on the basis of their respective alternate understandings of the problem of steering for sustainable development in the era of globalization.

In India, peoples' movements continue to work on the basis of the proverbial hope that "necessity is the mother of invention". But this proverb has been now subjected to a rigorous historical cum theoretical examination by the students of technological change[42]. Their historical analysis tells us that though social needs are a powerful force for the development of innovations as well as inventions but this proverb does not contain the whole truth about the process of innovation. The proverbial truth is borne out only in the sense that invention is at bottom a linking of some purpose or need with an effect that can be exploited to satisfy it. Societies need the inputs of creative individuals to produce inventions[43].

The originators and their teams are however known to play a very important and distinct role in the process of collective invention. They have the onus of conceiving the new combination of functionalities, which means conceptualizing how the building blocks of invention can be put together in the given context. It is to however be kept in mind that

[42] Marx, Schumpeter, Ogburn, Gilfillan,, Usher, Arrow, Schmookler, Rosenberg, Nelson, Freeman, Paul David and Arthur are some of the names who have dealt with the process of technological change by reflecting on the determinants of the processes of invention, innovation and diffusion.

43 The process of collective invention does not need the incentive of strong intellectual property rights to get the originators going on with the task of investing their energy and time to solve the pressing problems facing them. Rewards that the contributors seek are patronage, recognition and prizes. Patents have never been crucial to the processes of radical inventions.

even while the originators are known to play a very distinct role in the origination of inventions, they are not historically speaking autonomous in their actions. Embedded as they are in the historical state of science and engineering they are always acting collectively. Not all of them are necessarily working in close cooperation. They work as a part of the communities of practitioners and usually help build the new community of practitioners when the invention involved is a radical one.

The distinct character of originators is largely evident from the fact that they are steeped in the practice and theory of the principles or phenomena. They have the functionalities of invention in their reach. The originators are expected to have the building blocks of the invention in their possession through their team. Functionalities are understood by them in depth, and in practice they are known to be experimenting themselves with those functionalities. They are known to use the known elements in new combinations, which are used by them to provide non-standard solutions to the overall problem. And if the problem is itself ill-understood then the invention is characterized as a radical invention.

Particularly in the case of radical inventions, historical experiences suggest that radical changes begin within networks of pioneering organizations, technologies and users that form a niche practice on the margins of the regime. These niche situations (e.g. niche applications, demonstration programmes, social movements) provide space for new ideas, artifacts, and practices to develop without being exposed to the full range of pressures that favour the dominant regime[44]. Research has looked at the internal dynamics of alternative, sustainable niche development, sometimes situating niches at the base of a multi-level system, beneath incumbent socio-technical regimes and overarching landscapes. Models of multi-level transitions pose questions pose questions about whether different contexts lead to different transitions pathway, about relationships between scales (niche-regime-landscape), and about the dynamics of agency and power.

[44] Research has looked at the internal dynamics of alternative, sustainable niche development, sometimes situating niches at the base of a multi-level system, beneath incumbent socio-technical regimes and overarching landscapes. Models of multi-level transitions pose questions pose questions about whether different contexts lead to different transitions pathway.

This brief theoretical review is quite clear that the process of invention is a collective process. But the peoples' movements are yet to recognise this truth. Recently when the community working on technological alternatives for biomass based approach to rural industrialisation met in Mumbai to celeberate the work of K.R. Datye, an irrigation engineer and originator of some important contributions in this area. His contributions and life time work in the area of development of water resources mad it evident that the peoples' movements are yet to be associated with him and other such initiatives in a systematic way. The author himself reminded the participants of this meeting about the character of the debate that took place during the freedom movement and immediately after gaining political independence among the three most influential schools of economic thought namely, Nehruvians, Gandhians and Left including Communists on the potential of village industries to contribute to the development of sustainable livelihoods in rural areas. The author himself pointed out that the vision that K.R. Datye articulates along with his team in the book entitled "Banking on Biomass: A New Strategy for Sustainable Prosperity based on Renewable Energy and Dispersed Industrialization" was a step away from the approach of development economists. And that such an approach was still not present even implicitly in any of the different conceptions that the peoples' movements are pursuing even today after sixty years. Today also debate continues among the academics on how and to what extent the rural industries can contribute to the development of sustainable livelihoods in India. Till this day consensus eludes on this important subject[45]. Policymakers are divided on how the government should be intervening to realise the contribution of rural industries to the development of sustainable rural livelihoods[46]. However, debate has not ceased to exist even among the

[45] Studies undertaken by Ashwini Saith, Thomas Fischer & Vijay Mahajan, and Daniel Start, Craig, Bhalla, N.C. Saxena, Barbara White Hariss, C.P, Chandersekhar and many others are an indication of growing interest in the subject of rural livelihoods. Special issues of Manpower Journal & Indian Journal of Labour Economics also confirm this interest. International donor agencies are also paying considerable attention to the issue of rural non farm sector studies.

[46] Though the Inter-Ministerial Reports of the Planning Commission and National Common Minimum Programme (NCMP) commitment are an indication of how the policymakers cannot get away from promoting the sector, but it can be seen from the differing conclusions regarding the policy recommendations on protection and promotion from the Abid Hussein Committee, S.P. Gupta Committee and Montek Singh Aluwalhia Committee in the span of less than a decade that they are divided.

social movements on the role to be played by the village industries and artisanal manufacturing[47].

3.3 Towards a new heuristics for the development of an alternate future vision and strategy

India is now a country of over one billion people and over sixty percent of her population is still dependent for their livelihood on the sector of agriculture and allied occupations. The Indian agriculture is itself in crisis. In its current state with the existing framework of agricultural development, the sector of agriculture is also not able to absorb additional labour[48]. So far by following the agro-industrialisation framework of green revolution approach the country has been externalising the production of industrial inputs to the metropolis. This has been hollowing out the rural economy of its potential for rural industrialisation based on agriculture. Agriculture is no more an important driver of sustainable growth for the rural industries. This is now being aggravated much further through the new corporate strategy of diversification into agriculture, aquaculture, animal husbandry, horticulture and floriculture using even more of external inputs than before. To realise its true potential as a driver for rural industrialisation it is quite clear that the strategy of development of agriculture itself must be changed in the long run. The framework of rural industrialisation needs to be realigned with the proposed strategy of agricultural development based on agro-ecological approaches. Then only the country would be able to get the desired results in respect of the productive absorption of labour in agriculture and rural economy in India.

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[47] In the circles of many social movements and non-governmental organisations where the influence of Gandhian ideology exists in a big way this issue is upfront and discussed actively even today in this country. Narmada Bachao Andolan, (NBA) and many other such movements that constitute the National Alliance of Peoples' movements, having their origin in the Gandhian and Socialist (Social democratic) ideology, advocate among the people support for a path of development in which the sectors of agriculture, village industries and artisanal manufacturing would be protected and planned to become the core developmental sectors of the Indian economy. In the environmental movements too, the Neo-Gandhian ideology dominates and its adherents seek support for the protection of traditional technique, community institutions, village industries and artisanal manufacturing. Even in the Communist Left too, attempts are going on in the direction of strengthening them as the people involved in these industries are from the class of rural poor among which their movements have a significant presence.

48 Dinesh Abrol (2005), "Towards an understanding of the technological and ecological dimensions of agrarian crisis in India", in the Proceedings of Seminar on Agrarian Crisis, Jamia Millia Islamia, March 24-26, 2005

It does need to be emphasised that the problem of providing gainful employment to the people is significantly huge in magnitude and cannot be ignored by those who are planning for the programmes of economic and technological development. In regard to the problem of absorption of labour, the problems of India and China are unprecedented. Solutions required are also going to be very different from the ones which we have seen being deployed by others to industrialise themselves. Their full employment problem can not be solved by either the path of persisting with traditional economy or through the conventional path of industrialisation. The planners would not be able to utilise successfully the conventional path of industrialisation to achieve the state of full absorption of labour in India, even under the path of peoples' oriented democratic transition, a path which the author prefers to capitalism for the development of productive forces in the Indian society,.

The "new state planners" would have to follow a new pathway of industrialisation to achieve the state of full labour absorption in a sustainable way. The author's reading of the situation is that fifty percent of the Indian population would be living for long time, if not forever, in areas dependent on rural economy based production systems. Rural industries need to be upgraded for the reasons of limitations of both infrastructure and employability of rural migrants in the metropolis and cities. But its full implications are yet to be realised; climate change may trigger thinking in this direction. In the context of agriculture, it is even necessary to realise that in many agro-ecological regions the problems of ecological sustainability have become today the biggest barrier to the enhancement of agricultural productivity[49]. The pathway that capitalist agriculture has been following is creating the metabolic rift in an acute way; it has ceased to be self-sustaining in the sense that it can no longer find the natural conditions of its own production within itself. In this pathway, nutrients have to be acquired through long distance trade and separate industries outside of the agriculture sphere. This creates a rift

49 Land, the earth (and the ecological cycles that define it), and labour, which is the metabolic relation between human beings and nature, constitute the two original sources of all wealth. If we want to heal the metabolic rift and achieve metabolic restoration, we are required to treat land and water as treasure, ones that must not be exploited for short term gain, but rather replenished through rational and planned application of ecological principles to agriculture (agro-ecology). And labour, being the physical embodiment of a key, can access the land's rich qualities to provide healthy food and many other means of livelihood.

in the natural cycles of soil fertility and waste accumulation. Today there are many more loops resulting in new imbalances introduced, thanks to the perusal of external input intensive agriculture and the additional of capitalist food chain based production of processed foods in the world system of agriculture.

At the wider social level, a rift has also been widening between humanity and the natural world due to the relation of wage labour and capital[50]. Private property in the earth's resources, the division between manual/mental labour, and the antagonistic split between the town and country illustrate the metabolic rift on a social level. Today the rift at social level is manifest in many ways in the pathway that the country is following, such as the primacy of corporate speculation in real estate, the loss of autonomy of subsistence farmers to the knowledge of "expert technicians", the tenants / landless labourers becoming alienated from the land and ceasing to be the custodians of land and water resources, and the demographic transition from rural farms to urban centres.

For the restoration of this rift, it is clear that today the humanity needs to move outside of capitalism and enter into a paradigm of development that solves the metabolic problem of not only agriculture but also of the economy as a whole at the level of both ecological and social sustainability. India cannot afford to follow the well-treaded path which is already producing one disaster after another in the developed capitalist countries. To what extent these societies would continue or be able to afford the above said limitations is not the most relevant thing to discuss in India. Only a small percentage of population is dependent on agricultures in these countries. In our case, the challenge of transition is quite different. The kind of transition that the western world experienced is not repeatable. India colonising others is neither desirable nor feasible. If the transition of western kind is more or less out of question for India, it is necessary that we look for a path way that solves our problems in a better and sustainable way.

[50] Marx explored the ecological contradictions of capitalist society as they were revealed in the nineteenth century with the help of the two concepts of metabolic rift and metabolic restoration. The metabolic rift describes how the logic of accumulation severs basic processes of natural reproduction leading to the deterioration of ecological sustainability. Marx's concept of metabolism is rooted in his understanding of the labour process.

The onus of supporting the original innovators / originator(s) in the collective endeavour of establishing the new pathway to development lies certainly on those social movements in whose views the neo-liberal policies are doing an irreparable damage to the health of agriculture and rural industries in India. Valuable evidence comes for these social movements from the past experience of the world on the creation of pathways. History tells us that all those countries that chose to follow a non-linear path in respect of development of capitalism were successful in emerging as prosperous countries. To ensure a higher degree of success in their endeavours, they not only exploited the contradictions of the then existing world system of capitalism but also were very careful to pursue the transition in a systemic way. They chose successfully the track of labour-intensive industrialisation, but which was also technologically upgrading. We have seen this earlier quite effectively being done in East Asia, be in the case of Japan or South Korea or Taiwan. Their nation state (s) succeeded in creating a national economic space which was competitive and technologically upgrading for their own emerging industries in the process of transformation of their economies from the state of economic backwardness to the state of modern production[51].

We are already seeing in the case of China that their own current path is by itself now unable to produce the same level of desirable results. The task of how to formulate a truly indigenous agenda for the development of agriculture and rural industries in a new non-linear way is quite urgent for both China and India. The author considers this task to be quite critical for the survival of poor rural petty producers, marginalised people in general and the Indian nation as a whole. However, it is also true that though this need has been expressed time and again, yet the task remains unaccomplished in India. Not that it is an impossible task; important starting points already exist in the country.

3.4 Leadership and sustainability of the collective processes: the nature of institutional challenge

However, it is important that we recognize the nature of challenge facing the people in respect of the development of collective processes is not a simple one. Take for example

[51] See Pomeranz, K., The Great Divergence: Europe, China and the Making of the Modern World Economy (Princeton, 2000); Pomeranz, K,

the radical popular view that the neighborhood communities of users and providers of various services such as water, energy, and infrastructure and health education would have to come together and how they can be provided for from local sources. While it is true that there exists much potential in the local human and natural resources based systems to provide for the basic needs of the people as a whole even today, but the challenge of building a system that works efficiently is not as simple as getting together the neighborhoods. The institutions needed to build, operate and manage are required to be crafted in the midst of unequal power as associations of producers of new services and products using technologies that are new and need power relations to be altered completely in the sphere of use of resources. This challenge is quite different from being members of the community or associations of users of water and energy to be provided from the large systems as ready made final products. Even the peroponents of radical view now recognize that in order to provide the marginalized people of their basic rights or entitlements in respect of water and biomass we would need at this stage the leverage of the external inputs which the state can offer in the form of the conditions of programme sanction and facilitate through the subsidized provision labour. Even this solution would effectively apply to the projects of infrastructure. But how we would realize the sustainability of production of goods and services in respect of projects that do not constitute to be part of the infrastructure and where the conditions of competition in production and commercial considerations are going to play a critical role.

Even the proponents of radical popular view do discuss some of the pertinent issues of innovation and diffusion. They recognise the importance of adequate capacity to produce and supply the needed input at a large scale, cost as shown to be depending on the performance of training and capacity building, vocational training and basic education, the supply and cost of capital demanding credit concessions, etc. These are the problems of getting the systems of state and society to change the innovation policy and practice landscape. However, to get going on this front, needless to say you need to have a good crop of start-ups, which are still lacking. These efforts would need a new set of social carriers. These individuals would need the moral and material support of the social movements. Such pioneering organizations are still small in number; this means the

experience is only beginning to be gained within the country. Although for quite some time the country has had a cooperative movement of the petty producers, but the cooperative institutions needed for cooperation in production have been far and few (Dinesh Bidi, Indian Coffee House, etc.

Since there exists only many credit and input supply or marketing cooperatives, in my view the challenge is therefore one of building the institutions of cooperation in production. We urgently need to build a large number of associations of producers. They will have to experiment and practice the art of creation of production systems based on an appropriate heuristics. They will have to learn by doing and learning before doing to understand the political economy of production and technology. Those who are able to internally develop among themselves the relations of planned cooperation, democratic participation and camaraderie would only succeed. To compete in the market economy and with the aim to change the power relations surrounding the production systems, it is also clear that they will have to depend on the systems of technologies which are able to function as the new forms of productive forces. If we are planning to implement a new techno-economic paradigm, as is the case with the proposed strategy of banking on biomass for the development of rural economy in particular, the challenge is one of developing the local economies as the multi-sectoral systems of networked planning of production units that bank on biomass for food, energy and materials.

There has been some effort within the PSM organizations to work in this direction, which is also yet to achieve its critical threshold. At the level of action research it is already going on at a few places in the country. It has produced a set of viable technology systems in the sectors of production of vegetable tanned leather, processing of fruits and vegetables, processing of oilseeds and pulses and bio-farming. In other areas, the stage is still one of development of the systems of technologies. But what is important about this effort is that it is based on the heuristics of development of local economies as systems in themselves for the purpose of making an ecologically and socially sustainable just transition at the level of the rural economy. This heuristics suggest that local economies are not just a village level economy but a system of network of smaller villages carrying

out largely primary production (S level), medium size villages having a higher level of concentration of agricultural laborers (M level), bazaar villages having a higher level of artisans and secondary production (B level) and nodal taluk level town where the level of secondary and tertiary production is high (N level). These economies are capable of being networked for the creation of large-scale networked production systems where the democratically formed associations of producers can become the social carriers of viable economic units of production.

3.5 Where do we go from here?

It has to be recognised that even in the case of this "invention", the object under perusal is a new techno-economic paradigm and system. The tasks involved in the creation of a web of technologies and institutions for realizing the radically different and new developmental strategy based on renewable bio-energy and dispersed industrialization are hugely time and effort taking. The leadership of peoples' movements is only beginning to recognize that the process of invention is a collective and cooperative endeavour. Human interaction and informal networks of originators play an important role at every step. At every step these processes enhance the effectiveness because they steep the originator in the knowledge, experience, tradition and wisdom that needs to be utilized to solve the problem. They provide suggestions of useful techniques and of principles at work in other domains. They can even help the originators see the problem differently. Lane and Maxfield (1997) talk about generative relationships that can induce changes in the way the participants see their world and act in it and even give rise to new entities, like agents, artifacts, even institutions. Human interaction also provides needed criticism to burst fanciful bubbles, and it provides equipment and know-how to bring the concept into physical reality.

The originators cannot by themselves succeed and bring forth entirely new on their own into existence. They do need team; in this case as well as a group is at work. Datye and his group have been championing the pathway that is quite radically different from what is under perusal today in the industrializing countries. In the case of radical inventions societies have to reinvent and mobilize themselves to solve the pressing problems of their

times. Science is the cognition of necessity, as Kosambi postulated while providing the definition of science. We will have to take note of the necessity or all these necessities that have been discovered by the originators only in parts and are being put to use as elements of heuristics and functionalities as building blocks of the radical invention that has been dreamt of by many of us.

Much more is required and will have to be done by taking science and technology further in the same direction in which some of the experiments are already working. Peoples' science movement has to pick the necessary threads from the experience that has been obtained, and get down once again to the task with an understanding that we are a movement for the development of peoples' capabilities and consciousness to instill in them the will not only for resistance against the mentality of there is no alternative but also for learning the art and confidence of how we can become the social carriers of a new techno-economic paradigm at this stage in the age of neo-liberal globalization.

3.6 Concluding remarks

In this article we have finally come down to the assessment of the role of mainstream social movements by analyzing their ongoing interventions across the board, for example, in respect of the articulation of selection pressures, building of adaptive capacity and the development of new organizations and tools for technological innovation. We have undertaken the assessment of their efforts with the aim to analyze their contribution towards facilitating the transition to a new socio-technical regime in the rural economies in India. We have briefly examined the specific experiences of select experimental interventions underway at the moment in various parts of the country to develop the required technological innovation system to achieve a more desirable socio-technical transition in the case of agro-food system in India. We have also taken a stock of the efforts being put in by the network of innovators active in the field of developing appropriate / alternate technologies for the sustainable development of rural industries to contribute to the stability, resilience, durability, robustness and sustainability of the socio-

technical transition that India needs to pursue for upgrading the local economies as systems in themselves in the process of building a self-reliant multi-level economy.

It is also clear that at the same time as a whole the country is failing to move rapidly towards a desirable socio-technical transition because the mainstream social movements have been unable to combine so far the agenda of social justice and ecological sustainability in the case of agro-food system. It is obvious that the marginalized rural people who are suffering most from the current agrarian crisis would have to be mobilized to create a pathway for the desirable socio-technical transition to achieve both, ecological as well as social justice. It is clear that the progressive social movements are required to take an active part in the articulation of selection pressures and the building of adaptive capacity by developing new social carriers of techniques for sustainable development of the agro-food system and acting as a countervailing power which would be capable of pressing the STI system to work towards the development of techniques for agro-ecological approaches combinable with endogenous multi-sectoral rural network systems of industrial development.

We argue that while the country debates how it should grapple in the short run with the agrarian crisis to provide succor to the suffering people, it is also becoming clear that in the long run the solution lies in making a transition to a new socio-technical regime in the case of Indian agriculture. The challenge is therefore one of not just how the social movements can press the state to solve the agrarian crisis but also of how they can help build and support the newly emerging social carriers of techniques. The social movements have a totally new challenge of social construction of technology. They will have to participate themselves as co-evolving actors in the process of transition and learn to steer the emergence of a desirable socio-technical regime. Participation in the process of steering for sustainable development would require from the social movements to develop the capacity for regulation, providing vision, learning to learn and help the social carriers to build their competencies for production and innovation and developing countervailing power structures to participate in the task of coordinating actors and networks.

To undertake the creation of new "social carriers of techniques" and the development of a suitable science, technology and innovation (STI) system for the development of rural economies in India, we seek the inclusion of the rural institutes, community polytechnics and other related institutions into the system of innovation for agriculture. It is clear that the country needs to address quite urgently the task of building a new community of practitioners for the benefit of the construction of a path of sustainable development of rural economies in the currently prevailing Indian conditions. Demonstrably the successful experiments show that in the future efforts for facilitating the sustainable socio-technical transition should be based on the heuristics of development of local economies as systems in themselves. It is also apparent that the new production systems would have to be competitive necessarily in respect of the use of social labour time and resources. To grapple with the issue of scale and scope of planning required for making an ecologically and socially sustainable just transition possible at the level of the rural economies under the currently prevailing conditions in India, we recommend an integrated approach to the develop the agro-food system in conjunction with the pace being created for rural industrialization embedded in the womb of newly emerging social carriers of techniques.

We have shown that the new social carriers of techniques would have to accumulate necessary countervailing bargaining power to be effective participants in the making of the sustainable socio-technical regime. Historical experience of successful experiments tells us that the new social carriers of techniques would therefore need to work far more efficiently while scaling up their efforts to make the sustainable socio-technical transition really possible and attractive. The rationale behind this approach is simple; the institutions needed to build, operate and manage are required to be crafted in the midst of unequal power. They would also need to compete with the large scale private monopolies operating in the economy for a considerable period of time. Fortunately, it seems that as in India the local economies are still capable of being networked for the creation of large-scale networked production systems the democratically formed associations of producers would be able to become the social carriers of viable economic units of production far

more easily. This would also enable the country to face better the challenge of labour absorption and environmental sustainability.

Finally we hve shown that many of the successful experiments have already brought out quite forcefully that the regenerative economy would have to be built on the basis of the principle of minimum use of external inputs of electricity, water, energy and materials. To maximize the well-being local economies would have to be shaped to become major providers of water, energy and infrastructure services. It seems that by taking up the development of rural industries as an integral part of the strategy of development of agro-food system that has its root in the agro-ecological approaches the new social carriers of techniques for sustainable development have been able to embed far more easily the new socio-technical transition in the agency and power of the rural labour and the peasant-artisan networks. In such a path where the strategy of development is on priority going to bank on biomass and solar energy (in various forms i.e., thermal, hydro, wind and small hydro) for the upgrading of local economies there would also be the benefit of reducing CO2 emissions, pollution control and arresting land degradation.

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